Exploring the Dynamics of Organizational Knowledge Transfer: Insights using Agent-Based Modelling on Individual Absorptive Capacity

by Thomas Dolmark

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Certificate of Original Authorship

I, Thomas Dolmark, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, the School of Computer Sciences, the Faculty of Engineering and IT at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in this document and it has not been submitted for qualifications at any other academic institution.

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List of Publications

Journal articles

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Dolmark, T., Sohaib, O., Beydoun, G., Wu, K., & Taghikhah, F. (2022). The Effect of Technology Readiness on Individual Absorptive Capacity Toward Learning Behavior in Australian Universities. Journal of Global Information Management (JGIM), 30(1), 1-21. https://doi.org/10.4018/JGIM.306245

Dolmark, T., Sohaib, O., Beydoun, G., & Taghikhah, F. (2024). Agent-based modelling of individual absorptive capacity for effective knowledge transfer. Journal of Ambient Intelligence and Humanized Computing. https://doi.org/10.1007/s12652-024-04826-7

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List of Abbreviations

Abbreviated Term	Full Term
ABM	Agent Based Modelling
ACAP	Absorptive CAPacity
AI	Artificial Intelligence
ANN	Artificial Neural Networks
BDI	Belief Desire Intent
BES	Basic Empathy Scale
BES-A	Basic Empathy Scale - Adults
DGI	Delayed Gratification Inventory
IT	Information Technology
KPI	Key Performance Indicator
LSNS	Lubben Social Networking Scale
ODD	Overview, Design concepts, Details
PECS	Physical conditions, Emotional states, Cognitive capabilities and Social factors
PMT	Protection Motivation Theory
ROADMAP	Role Oriented Analysis and Design for Multi-Agent Programming
UTS	University of Technology Sydney

Abstract

Knowledge transfer is important. Among the different barriers, recipient absorptive capacity is the dynamic capability to absorb knowledge and is a common barrier that has no clear solution. An organisation's absorptive capacity is not simply the sum of the absorptive capacity of its members. Individuals absorb knowledge at different rates and time plays an important role in the application of knowledge. The research gap is that there is currently no method to simulate knowledge transfer based on individual absorptive capacity or other characteristics. Agent-based modelling is a simulation method that takes into account an individual's heterogeneity, and simulation is a mixed research method that allows for experimental design that can be executed at a fast time scale without affecting the real world. Experimental design is used to observe how different values in parameters or variables affect a system. This thesis undertakes the tasks of modelling knowledge transfer using agent-based modelling. The first experiment models knowledge transfer using individuals' absorptive capacity experimenting with knowledge spillover. The results show that when knowledge is systematically being transferred individuals can never fully exploit knowledge. The second experiment maps affective states which is a framework for emotions of individuals' process of absorbing knowledge while experimenting with empathy. The results show that empathy spreads negativity and deactivation. Finally, the third experiment attempts to model the diffusion of information disorder. It experiments with agreeableness which is a personality trait also known as "loving" person. The results show that agreeableness reduces malinformation which is to use the truth to hurt someone. Ultimately, this thesis provides a process and a tool to model knowledge transfer using agent-based modelling allowing for visualisation. This would be beneficial to everyone including pedagogues who currently rely on waiting on students' failure to apply a remedial strategy. As with most novel research, this thesis has had to make assumptions due to its limitations, however, advances in research and technology will further improve this thesis' contribution.

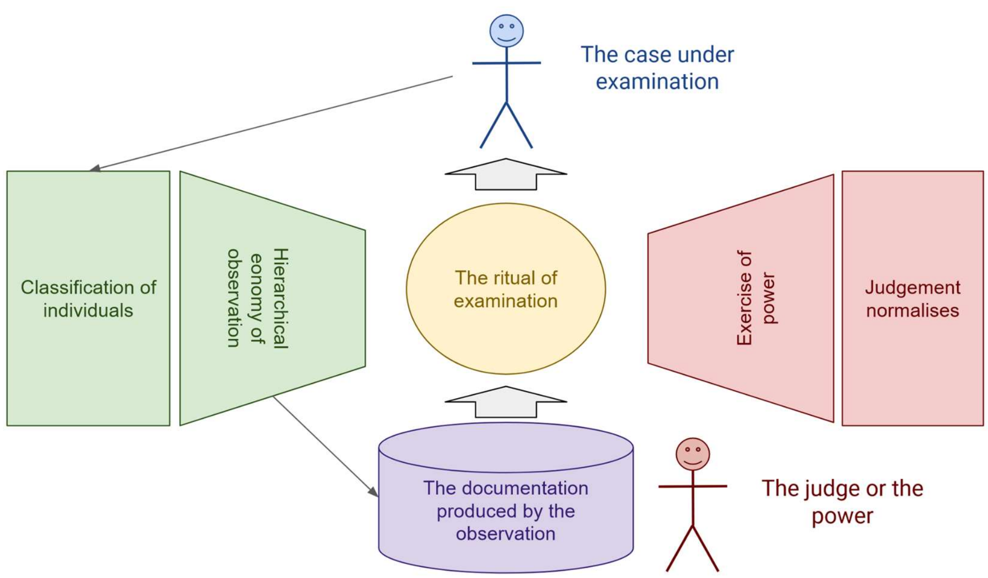
Chapter 1: Introduction

1.1 Statement of the Problem

Some organisations try to absorb knowledge from external sources (García-Morales et al., 2007). This differs from the process of formalising new knowledge which is also known as retentive capacity (Szulanski, 1996). Among the different barriers to knowledge transfer in organisations, causal ambiguity, an arduous relation between knowledge holder and recipient, and recipient's capability to absorb external knowledge were found to be the most common barrier (Szulanski, 1996). Absorbing external knowledge is referred to as Absorptive CAPacity (ACAP) (Cohen & Levinthal, 1990). Most of the research into ACAP has been into innovation, performance and knowledge transfer from the perspective of organisations (Jansen et al., 2005; Lowik et al., 2017; Yao & Chang, 2017). While this framework is popular for organisations, research has used it at an individual level (Lowik et al., 2017). However, individual ACAP as a barrier remains little researched (Gao et al., 2017; Lowik et al., 2017; Minbaeva et al., 2012). Cohen and Levinthal (1990, p. 131) states that "an organisation's absorptive capacity will depend on the absorptive capacities of its individual members" and that "a firm's absorptive capacity is not simply the sum of the absorptive capacities of its employees" (Jane Zhao & Anand, 2009). As individuals are part of organisations (Cohen & Levinthal, 1990, p. 131), organisation's knowledge transfer stems from individuals' behaviour (Minbaeva et al., 2012). Systems simulating individuals' decisions making provides researchers a bottom-up approach to human simulation (Crooks & Heppenstall, 2012). Agent Based Modelling (ABM) is a simulation where agents execute a variety of actions that create system-wide outcomes and behaviours (Crooks & Heppenstall, 2012). There are currently no simulation methods for knowledge transfer which make allowances for individual characteristics such as recipient ACAP or outliers.

1.2 Purpose of the Study

In the classroom, it is the teacher's responsibility to transfer knowledge to their students (Shulman, 1986). The teacher is trusted to know how to transfer the content of the knowledge as they have the knowledge of the content and pedagogy, and yet this requires them to have knowledge of the student that they are meant to teach (Shulman, 1986). To tackle this issue, the instructional approaches continuously return to the same traditional strategy. There will be a lecture, which will be followed by an assessment. When a student fails, it is feasible to identify areas of potential improvement; however, these strategies are only used to mitigate the consequences of failure, as they are assessed retrospectively. This process is repeated until a student attains a degree of "success" that is satisfactory for advancing to the next stage, or until they reach a level of "failure" that requires them to repeat the entire process until it is deemed fruitless for them. Foucault (1977, p. 187) means of correct training goes into the details of the process better.



This diagram is a basic representation of Foucault (1977, p. 187) means of correct training.

FIGURE 1. MEANS OF CORRECT TRAINING BY FOUCAULT (1977, P. 187)

As the famous quote often attributed to Albert Einstein says (Nissen, 2020):

"The definition of insanity is "doing the same thing over and over again and expecting different results"

Prevention strategies to avoid students failing to learn are absent as the ability to predict failures does not exist.

In classrooms, as the context of experimentation is live, research about education provided results that were more relevant than research conducted in laboratories which made implementation easier (Rosenberg & Koehler, 2018). Among the items that are important for learning are content and its context (Koehler et al., 2014). ABM can be imagined as a laboratory where the experiment's context which is made of agents and their attributes and behaviour can be changed to observe the repercussions over time over the course of multiple simulations (Crooks & Heppenstall, 2012). Conducting an experiment in a naturalistic situation is intricate, and the researcher faces the possibility of introducing uncontrolled confounding variables, some of which may not even be recognised by the investigator (Bell, 2009). The experiment may be influenced by uncontrolled factors that are associated with and alter the value of the dependent variable(s) (Bell, 2009). There is no definitive answer to the question of whether an experiment should be conducted in a controlled laboratory context or in a naturalistic field setting, which may provide more external validity (Bell, 2009). A laboratory environment provides greater control, yet the degree to which one can apply findings from lab-based studies to real-world situations is a subject of ongoing discussion (Bell, 2009). Conversely, it is simpler to establish a cause-and-effect relationship between two variables in a laboratory context (Bell, 2009). Researchers may classify studies without comprehensive or lab-based control as quasi-experiments (Bell, 2009). As a simulation is virtual, it has no repercussions on the real world and its participants.

At present, there are no simulation methods that take into account specific characteristics and exceptional cases in knowledge transfer. The lack of simulation approaches that address this divide is detrimental to both practitioners and academics, as it disregards the demands and viewpoints of the minority, leading to an imbalance. This novel methodology would enable future practitioners and scholars to delve further into the benefits of minority groups in respect to the subject matter.

1.3 Aim and Objectives

The aim of this research investigates simulation methods for knowledge transfer with a focus on individual characteristics and more specifically outliers. This research purpose delivers tools that can enhance knowledge transfer. Technology enables, enhances and creates new capabilities. Technologies developed by this research allows new methods and approaches for knowledge transfer.

The objectives of this research are:

- First, this research provides insights about parameters, variables, and factors that may affect individuals' learning and knowledge transfer in organisations.
- Second, this research investigates the methods of simulations for knowledge transfer that incorporate individual characteristics into the simulation. This is so outliers are presented in the simulation.
- Third, it investigates processes to model simulation.
- Fourth, this study presents the capability to forecast knowledge transfer in an organisation and its effect on individuals.
- Finally, this study provides a model that can be repurposed for different future experiments.

Once said capability is developed, it will hopefully provide practitioners with the means to gain insights to address issues before they occur. This allows an active approach to knowledge transfer rather than remaining reactive or passive.

1.4 Research Question

Here follows the three research questions this thesis addresses:

RQ1: How does interaction between individuals affect organisational knowledge transfer?

RQ2: Does cognitive empathy affect affective states?

RQ3: How does high agreeableness affect the diffusion of information disorder?

Each question is answered with an experiment. Each experiment expands on the previous one by using additional frameworks which are explained in detail in the theoretical background.

1.5 Significance of the Study

The significance of the study is firstly for students but also for pedagogues and other stakeholders involved in education. As there are currently no means to model organisational ACAP from individual ACAP, practitioners such as pedagogues are left with their experience, intuition, and judgement to assess a student's learning outcome. This research will enable the simulation and thus observation of knowledge transfer and ACAP ahead of application thus providing better visualisation for anyone involved or affected in knowledge transfer students being the most important. With the rise of e-learning, the data provided by said platforms could be leveraged using or adapting the steps and process of this research.

This research contributes to the literature:

- Social media has the potential to utilise their extensive data to replicate the exchange of knowledge and its impact on individuals. This may enable people to anticipate, focus on, and intervene prior to the occurrence of any tangible acts in the real world. For instance, the dissemination of false or misleading information could be pre-emptively reduced using the simulations from this thesis to reverse engineer the path to the sources of these information disorder.

- Management could utilise this approach to effectively simulate knowledge transfer inside their organisation. This tool can also be utilised to anticipate the performances of individuals who hold positions of authority inside the organisation, such as managers, decision makers, and other influential individuals. This, in turn, enables more accurate forecasting and improved planning. Prusak (1997) citation of Hewlett-Packard's famous quote "If only HP knew what HP knows, we could be three times more productive!" illustrates the gap in modelling knowledge transfer.
- The education sector can utilise this tool to analyse the impact of information dissemination on their pupils at the beginning of a course, eliminating the need to wait for observations and enabling prompt response.
- Students, employees, and other individuals seeking knowledge would also gain advantages from this, since it would offer them a clear grasp of the sources and methods through which knowledge will be provided to them. They would know who to approach for information and would also profit from the indirect effects of this research.
- The field of Information Technology (IT) and Artificial Intelligence (AI) could be enhanced by the application of ABM in another context.
- Academia will of course benefit from further knowledge contribution.
- Innovation and creativity may benefit from research into an individual ACAP (Da Silva & Davis, 2011).

Regardless of the different stakeholders and their numbers, students remain the main beneficiaries of this research significance.

1.6 Scope

The general scope of this study is individual's learning and the diffusion of information disorder. This study conducts three experiments that each build on its predecessor. Experiment 1 models agent ACAP in an ABM simulation and observe the effect of knowledge spillover whether absent, absolute, or in-between on said agents. Experiment 2 models agent affective state during the ACAP process in an ABM and observe the effect of cognitive empathy whether absent or existing on an agents affective state. Experiment 2 build on from experiment 1 by reusing the ACAP framework. Experiment 3 models the information disorder (informing, misinforming, disinforming, malinforming) in an ABM and observe how Agreeableness affects diffusion of information disorder. Experiment 3 builds on top of experiment 2 as it uses an agents affective state to infer what information disorder an agent might execute. While each experiment provides unique answers, they as well build on top of each one expanding the insights provided. Using individual ACAP and other characteristics the diffusion of information disorder is modelled in an ABM. As this study focuses on knowledge transfer, students from education institution such as universities are an ideal population to collect data from as they are actively involved in knowledge transfer. Universities also have a diverse population which would potentially further the divergence served by ABM.

1.7 Thesis Outline

Chapter 1 has introduced this research. Chapter 2 reviews the literature to provide a basic understanding of knowledge transfer as well as the problem and its gap in the field. Research questions are then enumerated. Chapter 3 provides the theoretical background in detail that can be used for the following experiments. Chapter 4 discusses the research design which is a mixed method. Chapter 5 describes ABM along with its process and validation. This is followed by Chapter 6, 7 and 8 which are respectively experiment 1, 2 and 3. Chapter 9 is the conclusion which summarises the thesis, provides theoretical and practical implication, and recommendations for the future.

Chapter 2: Literature Review

This literature review discusses knowledge, its transfer, its importance and makes the cases for the different issues with its transfer. It concludes that recipients' ACAP is a barrier to knowledge transfer that has no solution yet and that an organisation's ACAP is not simply the sum of its members.

2.1 What is Knowledge?

Knowledge is intangible (Lopez-Cruz & Garnica, 2018). It is made of various abstract elements and it is dynamic in its structure and relies on intuition (Davenport & Prusak, 1998, p. 5). Davenport and Prusak (1998, pp. 2-6) defined data, information and knowledge as when data has meaning, it is information, and when information has been experienced, it is knowledge (Garavelli et al., 2002; Karlsen & Gottschalk, 2004).

2.1.1 Tacit Knowledge

There is an undefinable portion of knowledge which is named tacit (Polanyi, 1962, p. 90; 1967, pp. 4-5). Examples of tacit knowledge would be riding a bike or intuition. Tacit knowledge is difficult to transfer as it is personal and difficult to formalise (Goh, 2002; Polanyi, 1967, pp. 4-5). This implies that said tacit knowledge cannot be reduced nor codified into information (Lopez-Cruz & Garnica, 2018). It can therefore be subject to misinterpretation or dispute (Bhatt, 2001). This implies that tacit knowledge cannot be reduced nor codified into information (Lopez-Cruz & Garnica, 2018).

2.1.2 Solipsism and Experience

Experience is lived (Davenport & Prusak, 1998). Bradley (1893, p. 248) presents the argument that nothing can transcend experience and therefore nothing can exist beyond oneself which is interpreted as solipsism. Davenport and Prusak (1998) definition of knowledge implicitly places the validation of truth within experience. However, Bradley (1893, p. 248) argues that experience does not lead to solipsism with the following rationale:

To argue solipsism using experience, experience can be broken down into direct and indirect experience where direct experience is what is immediately presented to oneself and indirect experience is experience that is beyond what is presented (Bradley, 1893, p. 248). With direct experience, what is presented is not oneself (Bradley, 1893, p. 248). While oneself has not been transcended, there is still no justification to oneself if one accepts there is a boundary between oneself and reality (Bradley, 1893, p. 249). For solipsism to be proved, it must transcend direct experience (Bradley, 1893, p. 250). There is no direct experience of oneself (Bradley, 1893, p. 248). With indirect experience, if one were to accept a reality beyond what is presented, any rationale would invalidate the oneself necessary to justify solipsism (Bradley, 1893, p. 251). Ignoring this argument, if one were to reject the existence of others in a reality beyond when thinking about the past, one would have to reject the past oneself for not being the same oneself now (Bradley, 1893, p. 253). By rejecting others, solipsism is ruined (Bradley, 1893, p. 255). Whichever rationale or reason, solipsism is ruined. Even though one's will and feelings are their own, that there is nothing beyond one self's experience is a fallacy even if one can only experience it (Bradley, 1893, p. 260).

Bradley (1893) rationale points out that even though experience is internal it relies in some manner on the exterior.

2.1.3 Warrant

Plato (1999) states knowledge as justified true belief (Vance & Eynon, 1998). The element of truth in knowledge lies in between justification and beliefs (Plato, 1999). Plato's definition of knowledge explicitly states the truth and places it between justification and belief (Vance & Eynon, 1998). For a person to have knowledge, it requires justification, truth and belief (Vance & Eynon, 1998). Plantinga (1993) circumvents the justification requirement by proposing instead warrant (Vance & Eynon, 1998). Warrant is the subjective quality which underpins justification (Merricks, 1995; Vance & Eynon, 1998). Vance and Eynon (1998) cites Plantinga (1993) which proposes that there are four general factors for warrant:

- the source presents its credibility or assumptions as honest;
- the context of the information is thought to be true;
- the information is believed to be transparent about its biases;
- and the general information within the message is perceived as clear.

2.2 Knowledge Transfer

The transfer of knowledge is a communication process which begins with the sender encoding information (Vance & Eynon, 1998). This information is then transmitted across a medium which can be subjected to pollution (Vance & Eynon, 1998). Finally, this information is collected and decoded by a receiver (Vance & Eynon, 1998). The codification and de-codification are affected by the subjects' objectives, experiences, values and context (Garavelli et al., 2002).

2.2.1 The Value of Knowledge

When knowledge is not used, it loiters, until it becomes redundant (Prusak, 1997). This led to Hewlett-Packard's famous statement (Prusak, 1997):

"If only HP knew what HP knows, we could be three times more productive!"

Knowledge can only be of value if it can be accessed when it is needed (Karlsen & Gottschalk, 2004). It is useless if it is accessed in hindsight (Kuo & Lee, 2009; Othman et al., 2014). In organisations, knowledge is relevant, time and task sensitive (Garavelli et al., 2002; Kuo & Lee, 2009; Othman et al., 2014; Vance & Eynon, 1998). Organisations that are aware of this attempt to transfer knowledge where it can be used (Kuo & Lee, 2009; Vance & Eynon, 1998). And yet being overwhelmed with information yields little value, only information that an individual reflects or learns has value (Kuo & Lee, 2009).

2.2.2 The Impact of Knowledge

Managers who do not leverage knowledge are jeopardising their operations (Luca et al., 2016; Prusak, 1997). As competition pressures businesses to leverage knowledge the need for managing it increases (García-Morales et al., 2007; Iyengar et al., 2015; Prusak, 1997). Knowledge is considered critical for organisations to succeed (Garavelli et al., 2002; Goh, 2002; Hwang et al., 2008; Karlsen & Gottschalk, 2004; Othman et al., 2014). Organisations that recognise the importance of knowledge spend significant amounts of resources to manage it (Iyengar et al., 2015). In the knowledge space, innovation and learning are the two dynamic sources (Savin & Egbetokun, 2016). When organisations uses IT resources to manage knowledge, it allows for them to build their capabilities further such as organisational innovation and they gain a strategic competitive advantage (García-Morales et al., 2007; Iyengar et al., 2015; Lin et al., 2004; Szulanski, 1996) along with other benefits such as less reinventing of wheels, less work generated, fewer questions, better decisions, error reduction, more independence for knowledge workers, improved customer relations, service and profitability (Karlsen & Gottschalk, 2004). Also, when a project ends, its resources are scattered along with its knowledge which is to the detriment of the organisation (Karlsen & Gottschalk, 2004; Prusak, 1997).

2.3 Factors of Knowledge Transfer

In the process of knowledge transfer, characteristics of the knowledge, source, recipient, and context according to prior research influence the difficulty of said process (Szulanski, 1996; Teece, 1977). To refer back to Plantinga (1993), warrants which supersedes justification, is determined by the source; the context; the information (Vance & Eynon, 1998). Szulanski (1996) enumerates the different sub-factors for these three categories that might impede knowledge transfer.

2.3.1 Context of said Knowledge Transfer

A barren organisational context and an arduous relationship between knowledge holder and recipient define the context of the knowledge transfer (Szulanski, 1996).

Barren Organisation

Knowledge transfer within an organisation is integrated within its context (Szulanski, 1996). The characteristic of said context would affect the gestation and evolution of these transfers (Szulanski, 1996). A fertile context is one that facilitates the development of these transfers (Szulanski, 1996). A barren organisational context is one that hinders the development of processes for knowledge transfers (Szulanski, 1996). The outcome and number of attempts to transfer knowledge was shown by previous research to be influenced by the sources of coordination and expertise, behaviour-framing attributes, and formal structure and systems of an organisational context (Burgelman, 1983; Ghoshal & Bartlett, 1994; Szulanski, 1996).

Arduous Relationship

Knowledge transfer might need multiple individual exchanges even more so when it includes tacit components (Nonaka, 1994; Szulanski, 1996). The overall relationship between the source and recipient (Marsden, 1990), and the ease to communicate would influence said transfer (Szulanski, 1996). Conversely, an arduous relationship would hinder knowledge transfer (Szulanski, 1996).

2.3.2 Knowledge Sources

Knowledge sources is an antecedent to ACAP (Zahra & George, 2002). The diversity of external knowledge sources influences ACAP (Lowik et al., 2017; Zahra & George, 2002).

Lack of Motivation

A knowledge source may withhold critical information from being unwilling to spend resources and time to support the transfer, from being afraid of losing ownership, from not being properly rewarded when sharing hard won victories, or to maintain a position of superiority or privilege (Szulanski, 1996).

Not Perceived as Reliable

When the source is an expert or trustworthy, it has a better chance to influence a recipient's behaviour (Szulanski, 1996). On the other hand, when the source is not trustworthy, it is not perceived as reliable and its advice or examples will be more resisted or challenged making any transfer more difficult (Szulanski, 1996). Once more, the acquisition capability of ACAP relies that all parties trust each other (Jacobs & Buys, 2010).

2.3.3 Knowledge Characteristics

Causal Ambiguity

When the factors or their interaction are ambiguous, it will make replication more difficult (Szulanski, 1996). Causal ambiguity manifests when even after successful or failed replication, a list of reasons nor their contributions cannot be established (Szulanski, 1996). Many arguments have been proposed such as using knowledge in a new context that is not properly understood or uncertainty that cannot be reduced (Szulanski, 1996). When it comes to knowledge transfer, the tacit portion of knowledge has often been the main attribute that has been considered (Grant, 1996; Nonaka, 1994; Szulanski, 1996). Although the undefinable tacit portion of knowledge is an embedded tacit human skill (Polanyi, 1962, p. 49), it can also be present in collective knowledge (Kogut & Zander, 1992; Szulanski, 1996).

Unproveness

Knowledge is less difficult to transfer when it has been proven to be of use in the past which asserts its robustness (Szulanski, 1996). When selecting knowledge to transfer, this assertion helps in the process (Szulanski, 1996). Otherwise, transfer would be more difficult to engage recipients or when attempting to legitimise controversial knowledge (Szulanski, 1996).

2.3.4 Knowledge Recipient

Characteristics of knowledge recipients includes ACAP and also a lack of motivation and a lack of retention capacity (Szulanski, 1996).

Lack of Motivation

There is ample documentation reporting how some recipients refuse to accept external knowledge which is also sometimes known as "Not Invented Here syndrome" (Katz & Allen, 1982; Szulanski, 1996). Passivity, hidden sabotage, feigned acceptance, foot dragging, or outright rejection in the implementation and use of new knowledge are examples of lack of motivation (Szulanski, 1996).

Lack of Retentive Capacity

Knowledge transfer can only be effective if it is retained (Szulanski, 1996). When a recipient does not have the ability to "retain" knowledge, challenges during transfer might be an excuse for not using it and when possible, reverting to the previous status quo (Szulanski, 1996). The capability to retain knowledge is reflected by one's ability to institutionalise it (Szulanski, 1996).

Absorptive CAPacity (ACAP)

Cohen and Levinthal (1990) first introduced the concept of ACAP as an organisation's capability to absorb knowledge. This differs from the process of formalising new knowledge also known as retentive capacity (Szulanski, 1996). ACAP was initially conceptualised from individuals' learning cognitive ability (Cohen & Levinthal, 1990). ACAP is a framework representative of an individuals' cognitive process.

2.4 Barriers to Knowledge Transfer

However, even if organisations fully commit to knowledge management, barriers to knowledge transfer can still exist (Szulanski, 1996). In organisations, the most common barriers are causal ambiguity, an arduous rapport between knowledge holder and recipient, and recipient's ACAP (Szulanski, 1996). Motivation was discovered to not be a barrier in knowledge transfer (Szulanski, 1996).

2.4.1 Causal Ambiguity

Causal ambiguity is when the cause of an effect is uncertain or unknown (Szulanski, 1996). Causal ambiguity is more likely to be addressed when subunits share knowledge (Uygur, 2013) which can be accomplished with cross-functional communication flows in horizontal structured organisations.

2.4.2 Rapport between Knowledge Holder and Recipient

An arduous relation between the knowledge holder and recipient is another barrier to knowledge transfer (Szulanski, 1996). Withholding critical information is considered as a mean to assert power by managers (Goh, 2002). This is believed to stem from a punitive and distrustful organisational culture rather than a technological issue (Goh, 2002).

2.4.3 Horizontal structures are a solution

Horizontal structures have a positive effect by promoting trust and by disseminating aspiration (Goh, 2002; Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013). These structures differ from the traditional vertical hierarchy as they allow communication to flow across business functions (Goh, 2002). Horizontal organisational structures appear to be an effective solution to causal ambiguity, and create rapport between knowledge holder and recipient (Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013). ACAP remains unaffected and unresolved by horizontal structures.

2.5 Conclusion

While Cohen and Levinthal (1990) acknowledge the difference between individual and organisational ACAP, Zahra and George (2002) ignore it (Todorova & Durisin, 2007). Organisational ACAP may be far more complex than individual ACAP (Cohen & Levinthal, 1990; Crossan et al., 1999; Todorova & Durisin, 2007). As research into ACAP from the perspective of organisations is favoured (Jansen et al., 2005; Lowik et al., 2017; Yao & Chang, 2017), research into individual ACAP as a barrier while existing is little, and thus making it rare (Gao et al., 2017; Lowik et al., 2017; Minbaeva et al., 2012). Cohen and Levinthal (1990, p. 131) states that "an organisation's absorptive capacity will depend on the absorptive capacities of its individual members" and that "a firm's absorptive capacity is not simply the sum of the absorptive capacities of its employees". As individuals are part of organisations (Cohen & Levinthal, 1990, p. 131), organisation's knowledge transfer stems from individuals' behaviour (Minbaeva et al., 2012). The combination of individuals' ACAP as a cognitive process would form the collectives ACAP as a collective cognitive process. This aggregation of cognition is not simply a matter of addition.

Chapter 3: Theoretical Background

This section covers theories of human emotions, cognition and behaviour laying the theoretical foundation for the experiments. First, the theory of ACAP is revisited to provide further knowledge of its history and its theoretical barriers. Then the concept of Stimulus-Organism-Response (S-O-R) discusses causality and its limits. This opens up the discussion for other topics such as the pleasure principle which argues that a person always seeks pleasure and avoids displeasure, which is discussed in the next section This is followed by the theory of planned behaviour which conceptualises the different factors that determine an individual's behaviour. Then personality traits continue the discussion of behaviours as a means to measure a person's personality. Following this, the topic of affective states redefines emotions enabling a different approach. This leads to the topic of empathy and its concepts. Cognitive style then introduces the topic of cognition. Finally, the Cognitive-Affective Personality System Theory discusses a holistic system to model human behaviour. The colour wheel of love is then discussed as a means to differentiate a person’s intent. This is then used as a bridge into a discussion of information disorders such as disinformation, misinformation, and malinformation and their underlying intent. This chapter concludes with a statement arguing the benefits of frameworks.

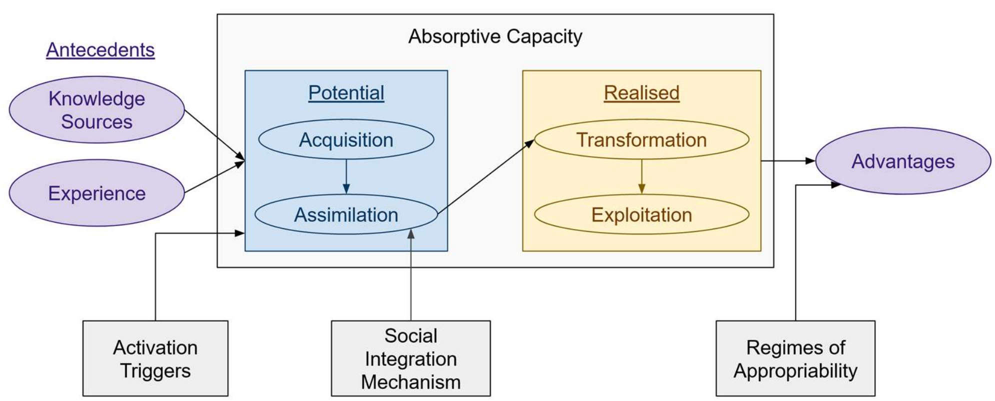
3.1 Absorptive CAPacity (ACAP)

3.1.1 Absorptive CAPacity (ACAP) Revisited

Zahra and George (2002) further developed a conceptual framework illustrating ACAP. It recognises four different capabilities in its absorption process (see figure 2):

1. **Acquisition** is the first capability where the object of knowledge is acquired (Zahra & George, 2002). In this capability, trust between all parties, identifying the recipient’s knowledge gap and evaluating available processes and tools are all critical (Jacobs & Buys, 2010).

2. In the **Assimilation** capability, the knowledge is extracted from the object (Zahra & George, 2002). The communication channel and processes must be sound for Assimilation to be effective (Jacobs & Buys, 2010). Hence, Social Integration Mechanisms are part of Assimilation which differentiates it from Transformation (Zahra & George, 2002).
3. **Transformation** is where processes are re-configured so that the newly acquired knowledge can be exploited (Zahra & George, 2002). The existence of prior knowledge processes affects this step (Jacobs & Buys, 2010; Szulanski, 2000). The deeper the prior knowledge processes are ingrained, the more time and effort it will take to unlearn and relearn the new process (Szulanski, 2000).
4. **Exploitation** is the final capability. In this instance, knowledge is used and its value is returned (Zahra & George, 2002). Exploiting knowledge is often viewed as a successful demonstration that knowledge has been absorbed (Jacobs & Buys, 2010).

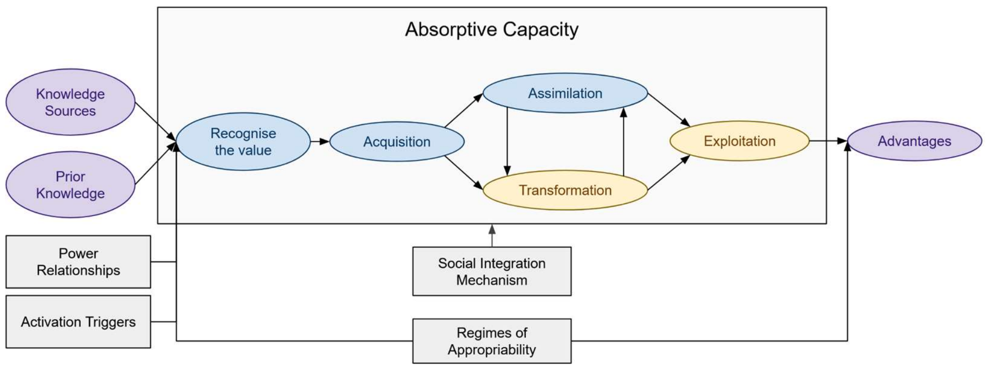


This diagram illustrates Zahra and George (2002) Absorptive Capacity.

FIGURE 2. ABSORPTIVE CAPACITY

3.1.2 Absorptive Capacity (ACAP) Reconceptualised

Todorova and Durisin (2007) later offered another reconceptualised version of ACAP. Here follows some differences Todorova and Durisin (2007) version of ACAP has from Zahra and George (2002) version.



This diagram is Todorova and Durisin (2007) Re-conceptualisation of Absorptive Capacity.

FIGURE 3. RECONCEPTUALISED ABSORPTIVE CAPACITY

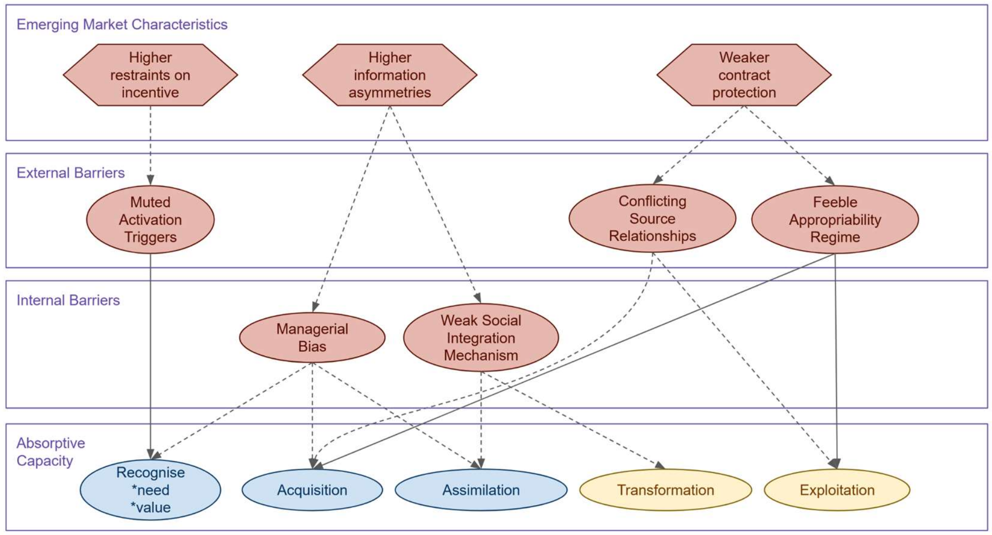
Acquisition, Assimilation, Transformation and Exploitation are empirically distinct (Jansen et al., 2005; Todorova & Durisin, 2007). Without prior knowledge, new knowledge cannot be evaluated and therefore cannot be absorbed (Cohen & Levinthal, 1990; Todorova & Durisin, 2007). Scholars have often included value recognition with Acquisition (Todorova & Durisin, 2007). Nevertheless, value recognition is supported to be another capability along with the four capabilities of ACAP (Cuervo-Cazurra & Rui, 2017; Todorova & Durisin, 2007). With this the regime of appropriability influence is moved to value recognition and exploitation (Todorova & Durisin, 2007). Assimilation and Transformation are alternatives not subsequent capabilities (Todorova & Durisin, 2007). Social integration mechanism influences all capabilities rather than just assimilation (Todorova & Durisin, 2007). An individual ACAP is made of prior knowledge and experience (Jane Zhao & Anand, 2009; Lowik et al., 2016).

3.1.3 Dynamic Capability

This framework is not hard defined, it is dynamic (Zahra & George, 2002). A capability is dynamic when its resources and competencies are combined to expand its dimensions to gain an advantage (Teece et al., 1997). Said resources can be developed, deployed and protected while said competencies can be internal or external (Teece et al., 1997). A dynamic capability is also influenced by its environment (Teece et al., 1997).

3.1.4 Barriers to Absorptive CAPacity (ACAP)

While there has been little analysis on barriers of ACAP (Matthyssens et al., 2005), Cuervo-Cazurra and Rui (2017) reconceptualised ACAP contingencies from previous literature (Cohen & Levinthal, 1990; Todorova & Durisin, 2007; Zahra & George, 2002) into barriers and separated these into internal barriers with managerial biases and weak social integration mechanisms; and external barriers with muted activation triggers, conflicting source relationships and feeble appropriability regimes. These barriers are heightened by characteristics from emerging market which are higher restraints on incentives, higher information asymmetries, and weaker contract protection from an unreliable judicial system (Cuervo-Cazurra & Rui, 2017).



This diagram presents the barriers of Absorptive Capacity from Cuervo-Cazurra and Rui (2017)

FIGURE 4. BARRIERS OF ABSORPTIVE CAPACITY

Dotted arrows are variables discovered by Cuervo-Cazurra and Rui (2017) while solid arrows are variables discovered in other previous research (Cuervo-Cazurra & Rui, 2017).

Higher Restraints on Incentives and Muted Activation Triggers

Withholding incentives limits information that drives individuals to seek external knowledge which inhibits activation triggers (Cuervo-Cazurra & Rui, 2017). Higher restraints on incentive strengthen muted activation triggers which then limits the recognition for the need and value of external knowledge (Cuervo-Cazurra & Rui, 2017). Ignorance is bliss. While activation triggers act as a signal that is both credible and visible which reduces the information asymmetry between what individuals perceive as a need and what they actually need, separating the need and value of recognizing external knowledge allows to describe the influence of incentive on recognition as an individual may recognise the need of external knowledge but may lack incentive to act upon said signal rapidly (Cuervo-Cazurra & Rui, 2017). While Zahra and George (2002) discussed the recognition of the need to search external knowledge, Todorova and Durisin (2007) spoke differently of the recognition of the value to search external knowledge (Cuervo-Cazurra & Rui, 2017). In summary, muted activation triggers affect recognition of the need for the recognition of the value of external knowledge (Cuervo-Cazurra & Rui, 2017).

Higher Information Asymmetries, Biases, and Weak Social Integration Mechanism

Missing information intermediaries (Khanna & Palepu, 2010) and poor implementation of regulation (Djankov et al., 2002) results in information asymmetries which increases the negative impact of biases and weakens social integration mechanisms of ACAP (Cuervo-Cazurra & Rui, 2017). High information asymmetries support prejudices towards external knowledge and limits the recognition of need and value of knowledge, its assimilation and transformation which increases the harmful influence of biases (Cuervo-Cazurra & Rui, 2017). As there is less information to counter preconceived ideas about what is the right action to take, higher information asymmetry results in higher biases (Cuervo-Cazurra & Rui, 2017). Irrespective of an individual's level of education, the absence or lesser development of rating agencies and information intermediaries which provide unbiased assessments are unable to supply individuals with information to reduce prejudice about external sources of knowledge (Cuervo-Cazurra & Rui, 2017). In addition, individuals are unable to trust the rules of the game when institutions with clear regulations are less developed (Cuervo-Cazurra & Rui, 2017; Djankov et al., 2002). Instead, they end up using social network as informal institutions; however, these social networks can work both ways in that while they can address the weakness in institutions and contractual protection, they are made of individuals with similar background which may potentially lead to group thinking (Won-Woo, 1990) and in turn reinforce information asymmetry (Cuervo-Cazurra & Rui, 2017). ACAP effectiveness is constrained by biases that are not corrected as a result of higher information asymmetries (Cuervo-Cazurra & Rui, 2017).

Biases

As a form of prejudice whether in favour of or against a source of knowledge, biases can be a significant limit on the ability to integrate external knowledge (Cuervo-Cazurra & Rui, 2017). These biases and preferences can favour a particular strategy (Ocasio, 1997) that directs connections between activities that are not clearly visible (Cuervo-Cazurra & Rui, 2017; Prahalad & Bettis, 1986). Biases inform one's decision whether external knowledge is needed even when others may consider knowledge valuable

(Cuervo-Cazurra & Rui, 2017). One might also consider how decisions affect their social position and future long-term prospects (Cuervo-Cazurra & Rui, 2017). Biases from considering long term prospects can be explicitly reflected in one's attitude (Cuervo-Cazurra & Rui, 2017). Biases can also be implicit with the "not invented here" syndrome (Katz & Allen, 1982) which may stop one from fully integrating external knowledge even if they acknowledge its value (Cuervo-Cazurra & Rui, 2017). Biases limit the recognition for the need for external knowledge irrespective of its given value, the acquisition of external knowledge that may undermine one long term social position of making decisions, and the assimilation of external knowledge in the form of "not-invented-here" syndrome even if its need and value is recognised and it has been acquired (Cuervo-Cazurra & Rui, 2017).

Weak Social Integration Mechanism

Higher information asymmetry also further increases the negative impact of weak social mechanisms (Cuervo-Cazurra & Rui, 2017). Less developed educational systems which favour memorisation and delivery of information over independent thinking and creativity along with information intermediaries and weaker institutions hamper individuals' ability to obtain and use external knowledge (Cuervo-Cazurra & Rui, 2017). Social integration mechanism has been widely discussed in the literature (Cuervo-Cazurra & Rui, 2017). Said mechanisms allow for external knowledge to be integrated, transformed and create new knowledge (Cuervo-Cazurra & Rui, 2017). These include the provision of incentives and a supportive organisational structure (Szulanski, 1996) that allows complex knowledge to be taught (Kogut & Zander, 1992) and for individuals to position themselves within a relationship network (Cuervo-Cazurra & Rui, 2017; Tortoriello, 2015). As it is difficult to determine how an individual decides the importance and priority of which knowledge will be integrated and used, social integration mechanisms and their non-monetary rewards are therefore important for the knowledge assimilation and transformation (Cuervo-Cazurra & Rui, 2017). While large information asymmetries hinder the establishment of clear behaviour directives, the provision of non-monetary incentive to align objectives and behaviours with others desires reduces relationship problems which can help individuals function more efficiently and enable assimilation and transformation of knowledge which can lead to success (Cuervo-Cazurra & Rui, 2017). Rewards like mandates, salary increases and other highpowered incentives used for a particular action may be detrimental as it influences individuals to take action only when there is a reward (Cuervo-Cazurra & Rui, 2017). Weak social integration mechanism limits the assimilation and transformation of external knowledge regardless of if the knowledge has been recognised valuable and been acquired (Cuervo-Cazurra & Rui, 2017).

Weaker Contract Protection

With weak contract protection, individuals cannot rely on dispute resolution that is rapid and affordable by a judicial system (Cuervo-Cazurra & Rui, 2017; Zhao, 2006). With a less developed judicial system combined with lower regulation quality and lesser enforcement implementation, enforcing contracts becomes further uncertain (Cuervo-Cazurra & Rui, 2017; Djankov et al., 2002). Poor contract protection increases conflicting source relationship and feeble appropriability regime (Cuervo-Cazurra & Rui, 2017).

Conflicting Source Relationships

A source may have different objectives than its recipients or it may wish to keep a competitive edge (Cuervo-Cazurra & Rui, 2017). As knowledge-based resources are in nature intangible and non-rival consumption prevents exclusion once access has been granted, a source may be reluctant to share knowledge as once knowledge has been shared, it may be difficult to enforce any agreement (Cuervo-Cazurra & Rui, 2017). Without an external enforcement mechanism, a knowledge source is more likely to resort to internal mechanisms such as causal ambiguity , secrecy and organisational complexity (Quan & Chesbrough, 2010; Zhao, 2006), or human resource management strategies to protect themselves (Cuervo-Cazurra & Rui, 2017). Trust between parties is harder without a system to resolve disagreements (Cuervo-Cazurra & Rui, 2017). All these issues are intensified by weak contract resolution and protection from a weak judiciary system as conflicts between a knowledge source and the recipients that cannot be easily resolved will further limit one's ability to acquire and exploit external knowledge (Cuervo-Cazurra & Rui, 2017).

Feeble Appropriability Regime

As stated before, with very weak contractual protections, said contracts might be too slow or costly to prevent misuse of external knowledge thus the source may limit access to its knowledge to safeguard it (Cuervo-Cazurra & Rui, 2017). The owners of knowledge may use secrecy and internal processes to avoid spillover to prevent the unauthorised diffusion (Quan & Chesbrough, 2010; Zhao, 2006) as they cannot use the judicial system to ensure protection (Cuervo-Cazurra & Rui, 2017). The fear that others may copy and take advantage of one's effort further diminishes research and develop (Levin et al., 1987) which further hurts one's ability to sustain a competitive advantage (Cuervo-Cazurra & Rui, 2017). A feeble regime of appropriability from weak contract protection limits acquisition and exploitation from external knowledge sources (Cuervo-Cazurra & Rui, 2017).

3.2 A Holistic Perspective with Stimulus-Organism-Response (S-O-R)

The S-O-R model was derived from the simplistic view of input-output systems when the individual internal factors were deemed important enough to be accounted for (Jacoby, 2002). Many models attempt to unravel the secret of these internal factors devoting little to no attention to stimulus or responses (Jacoby, 2002). Jacoby (2002) argues that the boundaries between stimuli, organism and response may not be clear and changes in the model are not necessarily in sequence in which the concepts are presented. Sometimes it can be difficult to ascertain when a construct is a stimulus, organism or response (Jacoby, 2002). A phenomenon could be both a stimulus and a response (Jacoby, 2002).

3.2.1 The Problem with Causal Effect

Weiner (1985) argues that without causal analysis adaptation is not possible. There can be a multitude of explanations for a cause for any activity (Weiner, 1985). Knowing why an event has occurred has a practical purpose (Weiner, 1985). Fritz (1958) was the first to propose a systematic analysis of causal structure (Weiner, 1985). According to him, the most fundamental distinction regarding causes is: "In common-sense psychology (as in scientific psychology) the result of an action is felt to depend on two sets of conditions, namely, factors within the person and factors within the environment" (Kelman, 1958, p. 82; Weiner, 1985). Irrespective of discipline with little exception, behaviour models have been represented in some sort of input output model (Jacoby, 2002). Early models of behaviour contained what is now seen as untenable numerous assumptions (Jacoby, 2002). One of these assumptions was how people would behave "rationally" where the rationale was defined by an outside standard (the eye of the beholder) which meant that the differences and significance of mental states and processes became irrelevant (Jacoby, 2002). These models are often constructed using boxes, circles or some sort of rigid shape which are then connected using lines or arrows to describe a dynamic fluid process influenced by many phenomena (Jacoby, 2002). Given the number of permutations and combinations, there is an unlimited number of models that can be produced (Jacoby, 2002). And yet, within the process of designing these diagrams, the decision of which factor should be included or omitted in the model is left to the modeller which reflects a level of arbitrariness (Jacoby, 2002). What is of concern is how this rigid depiction might steer one away from noticing the more important phenomena and relations which would not help to understand even though this would not be an excuse to not point out its imitations (Jacoby, 2002). Also, all these shapes and lines might be intimidating for someone who has not been shown an explanation (Jacoby, 2002). Put all together to develop a new model all one has to do is to identify variables that appear important, place these into shapes on a page and draw connecting lines with a few recursive relations (Jacoby, 2002). Jacoby (2002) points out that this approach is a problem because it is not grounded in prior science but instead in the middle of things. The organisation and relations in causal structure should need empirical evidence (Jacoby, 2002).

3.2.2 Conclusion

Stimulus can elicit both cognitive (utilitarian) and affective (hedonic), and behavioural response (Bitner, 1992; Dubé et al., 1995; Im & Ha, 2011; Michon et al., 2005; Michon et al., 2008; Stoel et al., 2004).

3.3 The Pleasure Principle

3.3.1 Beyond Hedonism

Higgins (1997) pointed out that people are motivated to avoid pain and approach pleasure. In a situation, a behaviour that produces pleasure is likely to be repeated while one that produces pain is not (Higgins, 1997). The hedonism underpinning the pleasure principle has been used as an assumption in many areas in psychology to explain motivation such as theories of emotion in psycho-biology, conditioning in animal learning, decision making in cognitive and organisational psychology (Dutton & Jackson, 1987), consistency in social psychology, and achievement motivation in personality (Higgins, 1997). This assumption, while popular, is not the only way that the approach-avoidance motivation operates (Higgins, 1997). Given different environments, while the pleasure principle may appear to change, the dynamic of avoiding pain and approaching pleasure remains (Higgins, 1997). Higgins (1997) proposes regulatory focus, regulatory anticipation and regulatory reference to explain behavioural motivations.

3.3.2 Regulatory Focus

Animal learning-biological models (Lang, 1995), cybernetic-control models, and dynamic models differentiate ways to avoid undesired end state in order to approach desired end state (Higgins, 1997). They do not discern the different approaches to a desired end state nor are the different end states related to these approaches (Higgins, 1997). Regulatory focus is presented as the self-regulation to the different approaches towards different desired end states (Higgins, 1997). This self-regulation has been well documented (Elliot & Church, 1997; Elliot & Harackiewicz, 1996; Higgins, 1997). Regulatory focus critical characteristic is that it tries to minimise discrepancies between current and desired end-states (Higgins, 1997).

Promotion Regulatory Focus

A regulatory focus of promotion is concerned with advancement, growth, accomplishment and goals (Higgins, 1997). Its desired end state are strong ideals such as hope, wishes and aspiration (Higgins, 1997). Promotion focus is sensitive to both presence and absence of positive outcomes, and thus its strategy is inclined to approach matches by ensuring hits and avoiding errors of omissions (Higgins, 1997). Individuals following this strategy persist longer on more difficult tasks and are less likely to quit (Higgins, 1997). They have a risky bias to say yes (Higgins, 1997).

Prevention Regulatory Focus

A regulatory focus of prevention is concerned with protection, safety, and responsibility (Higgins, 1997). Its desired end states are strong "ought" such as duties, obligations, and responsibilities (Higgins, 1997). Prevention focus is sensitive to both presence and absence of negative outcomes; thus, its strategy is inclined to avoiding mismatches (Higgins, 1997; Higgins et al., 1994). Individuals following this strategy will be more vigilant to ensure safety and not losing however will quit more easily (Higgins, 1997). They will avoid making a mistake like false alarms or commission errors and attempt to correct rejections, for example, a person who would say "No, I have not seen that word before" in order to avoid a misunderstanding (Higgins, 1997). They have a conservative bias to say no (Higgins, 1997).

Self-Regulatory Focus to Strategy Inclination to Motivational Consequences

A strategy is a pattern in decisions using knowledge to meet objectives by ensuring desired outcomes against undesired ones (Higgins, 1997). Individuals use strategies to increase the likelihood to attain their desired end state (Higgins, 1997). Their inclination towards a strategy whether promotion-focus with aspirations and accomplishments or prevention-focus with responsibilities and safety can have different implications in performance, emotions, decision making, and so on (Higgins, 1997). The strategies in which individuals approach pleasure and avoid pain have consequences on their motivations (Higgins, 1997). Depending on an individual's regulatory focus, they would associate different pleasures and pains with objects and events (Higgins, 1997). While a momentary situation can induce a temporary promotion or prevention focus, self-regulation is influenced by standards that are chronic to the individual's experience and present in momentary situations (Higgins, 1997). An individual's strategic inclination is based on their self-regulatory focus (Higgins, 1997).

Activation and Valence

Higgins (1997) defines negative emotions like sadness or disappointment as dejection and considers from this a cheerful-dejection dimension. Higgins (1997) also recognises some emotions like feeling threatened or afraid to have an agitation element and places this on a quiescence-agitation dimension. It is reasonable to view that Higgins (1997) meant the cheerful-dejection dimension as valence and the quiescence-agitation dimension as activation. When an individual fails to meet their ideal (promotion focus) they experience negative emotions and when they fail to meet ought (prevention focus) they experience high agitation emotions (Ausubel, 1955; Higgins, 1997; Lazarus, 1968; Roseman et al., 1990). The pain from the absence of positive promotion focus on ideal outcomes is different from the pain from the presence of negative preventive focus "ought" outcomes (Higgins, 1997). While regulatory focus is intrinsic to the different kinds of pain experienced whether negative or high activation, an individual irrespective of his regulatory focus will experience both kinds of pain (Higgins, 1997). It is important to distinguish between the opportunity for accomplishment (promotion opportunity) and the opportunity for safety or security (prevention opportunity) and between the threat of nonfulfillment (promotion threat) and the threat of committing mistakes (prevention threat)(Higgins, 1997). While the strength of pleasant or painful emotions is proportional to the strength of regulatory focus (Higgins et al., 1997), the intensity of emotions is mediated by chronic regulatory focus (Higgins, 1997). The compatibility between chronic and momentary regulatory focus also influences memory (Higgins, 1997). Events that involve promotion or prevention are better remembered by individuals with respective chronic regulatory focus (Higgins, 1997).

Expectancy and Value

While Expectancy has been used in many ways to explain motivation, it is an important variable such as in motivational theories of animal learning, developmental psychology, social psychology (Feather, 1966), personality (Bandura, 1977), clinical psychology (Norem & Cantor, 1986; Scheier & Carver, 1992), and other areas (Higgins, 1997). Among the many theories on motivation, the Expectancy-Value model assumes that expectancy and value as independent variables when combined have a multiplying impact on committing to a goal (Higgins, 1997). When promotion or prevention focus is stronger the interaction between Expectancy and Value is respectively more positive or negative (Higgins, 1997).

3.3.3 Regulatory Reference

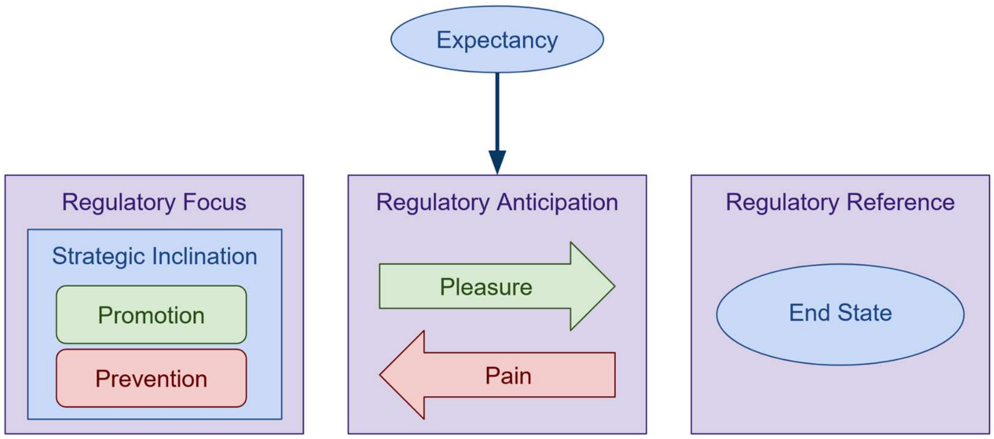
As Regulatory Focus is concerned about the focus of approach or avoidance, Regulatory Reference is concerned about the end state, and either desired or undesired is used as a reference point for self-regulation (Higgins, 1997). A positive reference is a desired end state where an individual reduces discrepancies as they move towards the end state (Higgins, 1997). A negative is an undesired end state where an individual amplifies discrepancies as they move away from the end state (Higgins, 1997). Psychology has a long history of distinguishing positive and negative reference values in self-regulation (Higgins, 1997).

3.3.4 Regulatory Anticipation

As Regulatory Focus regards approach or avoidance and Regulatory Reference concerns desired or undesired end state, in the same manner, Regulatory Anticipation conceptualises the anticipation of consequences whether it being anticipating receiving pleasure or not receiving pain (Higgins, 1997). As expectancy is an important concept in psychology that has been used in more than one way to explain motivation, knowledge of said expectancy would further help understand Regulatory Anticipation (Higgins, 1997).

3.3.5 Conclusion

To discover the real underlying nature of motivation, the pleasure principle must go beyond the hedonist foundations (Higgins, 1997). When neuroimages of brain responses fail to distinguish the different pleasures and pains, overreliance on said hedonism can mislead conclusions (Higgins, 1997).



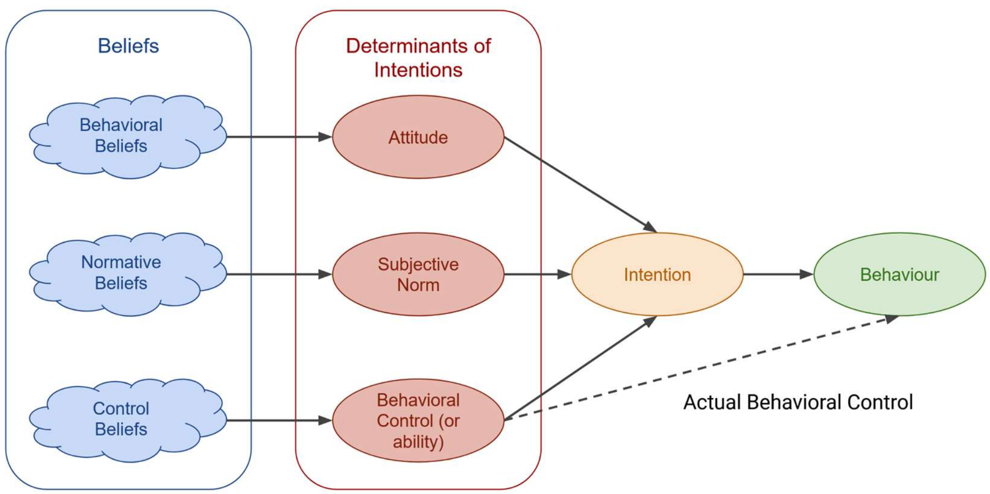
Here is a simple illustration of Higgins et al. (1994) Regulatory Principles.

FIGURE 5. REGULATORY PRINCIPLES

Higgins (1997) proposed Regulatory Focus, Regulatory Reference, and Regulatory Anticipation as a means to go beyond the hedonistic foundation of the pleasure principle while still respecting its dynamics. Regulatory Focus embodies the strategy of self-regulation by separating promotion focus approach strategies (ensure hits and against errors of omission), and prevention focus avoidance strategies (insure correct rejections and against errors of commission) (Higgins, 1997). Regulatory Reference embodies the movement in relation to a reference point whether by approaching a desired end state (discrepancy reducing), and avoiding an undesired end state (discrepancy-amplifying) (Higgins, 1997). Regulatory Anticipation embodies the direction based from anticipated consequences with either approaching anticipated pleasure or avoiding anticipated pains (Higgins, 1997).

3.4 The Theory of Planned Behaviour

Ajzen (1991) introduced the theory of planned behaviour that states that behaviour is influenced by beliefs. This theory is an extension of the theory of reasoned action (Ajzen, 1991). Ajzen (2011) released a revision of the theory by acknowledging other factors such as cognition and affection. According to environmental psychology, people's behaviour is affected by their reaction to environmental cues (Im & Ha, 2011). ACAP has been demonstrated to be a mediating factor towards behaviour (Dolmark, 2020).



This diagram illustrates Ajzen (1991) Theory of Planned Behaviour.

FIGURE 6. THEORY OF PLANNED BEHAVIOUR

3.4.1 Belief

The theory of planned behaviour posits that the function of salient information or beliefs is relevant to behaviour (Ajzen, 1991). The theory is underpinned by three types of beliefs:

- behavioural beliefs which are beliefs regarding attitude associated with a behaviour,
- normative beliefs who are made of subjective norms which are the subjective beliefs about social influences,
- and control beliefs which represent the element of perceived control and limit in a behaviour (Ajzen, 1991).

3.4.2 Determinants on Intentions

Attitude

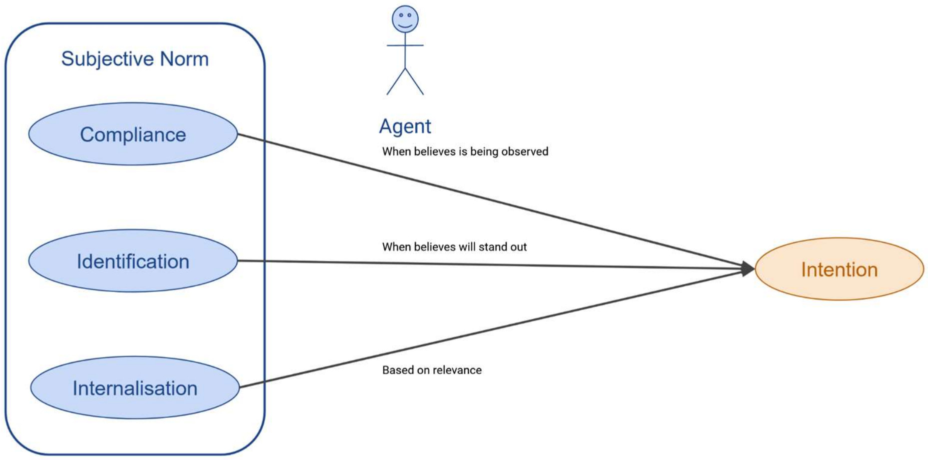
Allport (1933) is close to defining attitude with:

> "An attitude is a mental and neural state of readiness, organised through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related."

In the theory of planned behaviour, behavioural beliefs are a person's attitude towards a behaviour or in other words, how much they favour or unfavoured a behaviour (Ajzen, 1991).

Subjective Norm

The perceived social pressure to perform or not a behaviour is also known as subjective norms which are constituted of normative beliefs (Ajzen, 1991). Normative belief is an individual's belief that an agent or group who is important to them will approve or not of a particular behaviour (Ajzen, 1991). Motivation to comply was determined to suppress the prediction of an individual's behaviour (Ajzen, 1991). Kelman (1958) proposes three social processes where subjective norms are influential: Compliance, Identification and Internalisation.



This diagram illustrates Kelman (1958) Subjective Norms.

FIGURE 7. SUBJECTIVE NORMS

Compliance

Compliance is described as when an individual accepts influence because he wishes to please another person or group to obtain a reward or avoid punishment while still not agreeing with said person's or group's value (Kelman, 1958). The individual will only comply with social influences when he believes he is being watched by influential agents (Kelman, 1958). Here, the power of the agent's social influence is known as conformity (Kelman, 1958).

Identification

Identification often means that an individual accepts and defines himself based from the influence of another person or group (Kelman, 1958). The individual adopts the role of the other where his responses are defined by identity irrespective of values (Kelman, 1958). Identification tends to occur when the individual relation to the agent will stand out (Kelman, 1958). The individual will often identify with an agent he finds attractive (Kelman, 1958). An individual's perception of a system's usefulness is significantly influenced by the agent he identifies with (Venkatesh & Davis, 2000).

Internalisation

Internalisation is when an individual accepts influence because the values that are presented to match his own (Kelman, 1958). The individual will consider the influence to shape his behaviour or actions if it is a useful solution (Kelman, 1958). The individual will internally conform based on the agent's credibility (Kelman, 1958). The individual will accept the influence of the agent based on its relevance to an issue irrespective of being watched or standing out (Kelman, 1958).

Behavioural Control

Behavioural control is how difficult or easily a person is perceived in performing a behaviour (Ajzen, 1991). Past experience, anticipated impediment, and obstacles are assumed to reflect behavioural control (Ajzen, 1991). A behaviour's intention can only be expressed if a person decides of his own free will to perform or not a behaviour (Ajzen, 1991). While this may be true sometimes, other times a person's performance will depend on opportunities and resources (Ajzen, 1991). All this is the actual control a person has on a behaviour (Ajzen, 1991). As long as said person has the required resources and opportunity, and intention, they should succeed in doing so (Ajzen, 1991).

3.4.3 Intention

Intention is an indication of how much effort or how hard a person will try to perform a behaviour (Ajzen, 1991). Motivations that influence a behaviour are assumed to underpin intention (Ajzen, 1991). A behavioural performance should be as strong as its intention (Ajzen, 1991).

3.4.4 Behaviour

A behaviour is a collection of actions made by a person (Cao, 2014). The performance of a voluntary act can be predicted by measuring the intention of a behaviour (Sheppard et al., 1988). As time goes on, events that unfold in a person's life can affect their beliefs including behavioural, normative and control which would change attitudes, subjective norms and perceptions of control leading to intentions being revised (Ajzen, 2011). Again, the original model of the Theory of Planned Behaviour alas does not take into account affective states (Ajzen, 2011).

3.5 Personality Traits or the Big 5 O

Personality is the characteristics of thinking, feeling, and behaving of an individual (Letzring & Adamcik, 2015). Barrick and Mount (1991) argues that personality could be meant as how an individual is perceived by friends, co-workers, and supervisors which would be concerned by social esteem, regard, and status. A person's reputation can be used to summarise his past behaviour and predict what people might think about his future behaviour (Barrick & Mount, 1991). Examining links between personality traits and emotions can help understand the underlying mechanisms (Letzring & Adamcik, 2015). An important part of daily life is how a person feels which motivates them to behave in multiple ways (Letzring & Adamcik, 2015). The five factors personality trait classification is fairly robust (Digman, 1990) using different instruments, theoretical frameworks, in different cultures, and different samples (Barrick & Mount, 1991). The big five personality traits are Extraversion, Emotional Stability, Agreeableness, Conscientiousness, and Openness to Experience (Barrick & Mount, 1991). The precise meaning behind these dimensions has been subject of disagreements (Barrick & Mount, 1991):

- As the first dimension, **Extraversion**/Introversion is often associated with traits like assertive, sociable, talkative, gregarious, and active (Barrick & Mount, 1991). This dimension is thought to be made of Sociability such as sociable, exhibitionist, and expressive; and Ambition like initiative, surgency, ambition, and impetuous (Barrick & Mount, 1991).
- The second dimension which is also known with the previous dimension as the "Big Two" is referred to as Emotionality, Emotional Stability, or **Neuroticism** (Barrick & Mount, 1991; Conley, 1985; Hakel, 1974; Lorr & Manning, 1978; McCrae & Costa, 1985; Noller et al., 1987; Smith, 1967). Anxiety, depression, worry, insecurity, embarrassment and anger are its common traits (Barrick & Mount, 1991).

- **Agreeableness** or Likability among other names such as Compliance versus Hostile Non-Compliance (Digman & Takemoto-Chock, 1981), or Love (Peabody & Goldberg, 1989) is known to be the third dimension (Barrick & Mount, 1991; Conley, 1985; Hakel, 1974; McCrae & Costa, 1985; Noller et al., 1987; Smith, 1967; Tupes & Christal, 1992). Being courteous, flexible, trusting, good-natured, cooperative, forgiving, soft-hearted, and tolerant are traits often associated with this dimension (Barrick & Mount, 1991).
- As it has been frequently called, **Conscientiousness** (Botwin & Buss, 1989; Hakel, 1974; McCrae & Costa, 1985; Noller et al., 1987) or infrequently referred in the education achievement and volition setting as Will to Achieve (Botwin & Buss, 1989; Digman, 1989) or Strong-Willed (Smith, 1967), is the fourth dimension (Barrick & Mount, 1991). The difference in labels reflect a disagreement about the essence of this dimension (Barrick & Mount, 1991). Traits like dependability, being careful, thorough, responsible, organised, and planful are suggested to reflect this dimension (Barrick & Mount, 1991). Some authors have argued to include volitional aspects, such as hardworking, achievement-oriented, and persevering (Barrick & Mount, 1991; Digman, 1990; McCrae & Costa, 1985; Smith, 1967).
- The last dimension is known as **Openness to Experience** (McCrae & Costa, 1985), Culture (Hakel, 1974), or Intellect (Barrick & Mount, 1991; Digman & Takemoto-Chock, 1981; Peabody & Goldberg, 1989). Being imaginative, cultured, curious, original, broad-minded, intelligent, and artistically sensitive are common traits with this dimension (Barrick & Mount, 1991).

These five factors account for the data quite well which was discovered by researchers in every case (Barrick & Mount, 1991). Personality traits have some connections with affective reactions and important ones to experiencing emotions (DeNeve & Cooper, 1998; Larsen & Ketelaar, 1991; Letzring & Adamcik, 2015).

Table 1. Classification of Personality Traits and Affect.

	Positive Affect	Negative Affect	Change reported
Extraverts	More	Less	Positive induction
Neurotics	Less	More	None
Agreeable	Less	Less	None
Conscientious	More	More	Negative induction
Open to Experience	More	None	None

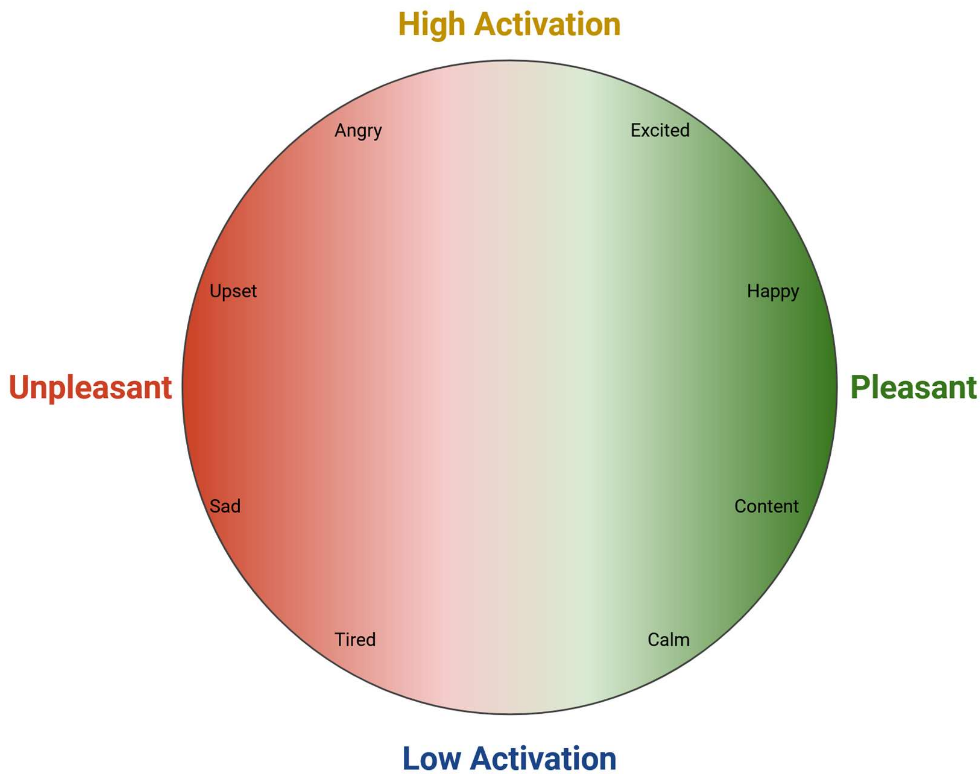
This table reports the relation between personality traits and affect by Letzring and Adamcik (2015).

Extraverts tend to experience less negative affect but more positive affect (Letzring & Adamcik, 2015). Neurotics tend to experience less positive affect but more negative affect (Letzring & Adamcik, 2015). Highly agreeable people tend to experience less negative affect and less positive affect (Letzring & Adamcik, 2015). Agreeableness is a moderating factor between neuroticism and negative outcomes (Letzring & Adamcik, 2015; Ode & Robinson, 2007). Also, people with high agreeableness tend to react less to aggression whereas people with low agreeableness when exposed to antisocial semantics will become more prosocial (Letzring & Adamcik, 2015; Meier et al., 2006). Conscientious people tend to experience positive affect and negative affect (Letzring & Adamcik, 2015). Finally, people open to experiences tend to experience positive affect but do not experience negative affect (Letzring & Adamcik, 2015). Extraverts responded to change after a positive induction (Letzring & Adamcik, 2015). Conscientious also responded to change but after a negative induction (Letzring & Adamcik, 2015). Neurotics, highly agreeable people and people open to experiences did not change after any induction (Letzring & Adamcik, 2015). It is important to consider that these personality traits are independent from cognitive ability (Barrick & Mount, 1991).

3.6 Affective States

Ajzen (2011) revised his theory to wishing he had included affection as well as cognition. While people intuitively know what emotions are and that they are important (De Houwer & Hughes, 2019; Russell & Barrett, 1999), its field is complex and vast (Russell & Barrett, 1999; Weiner, 1985). Some emotions exist without any expression such as awe, guilt and shame while other emotions share the same expression such as smiling for any positive emotion (Russell & Barrett, 1999). People have different intuitions about emotions but when it needs to be explained, there is no consensus (De Houwer & Hughes, 2019; Russell & Barrett, 1999). Emotions are used in everyday language; however, they lack a precise definition (De Houwer & Hughes, 2019; Russell & Barrett, 1999). Sometimes, it appears that everything is an emotion and its boundaries are fuzzy (Russell & Barrett, 1999). When definitions are based on theoretical and subjective ideas, debates often become fruitless (De Houwer & Hughes, 2019). There are many frameworks about affection such as Valence and Activation, Attribution and Motivation.

3.6.1 Valence and Activation



This diagram shows Feldman Barrett and Russell (1998) Semantic Structure of Affect.

FIGURE 8. SEMANTIC STRUCTURE OF AFFECT.

Phye et al. (2007, p. 108) defines different states of affection, and proposed a two-dimension approach with valence described as pleasantness and activation (Russell & Barrett, 1999; Tellegen & Watson, 1999). Activation refers to energy, motivation or arousal and valence pertains to pleasantness or hedonic tone (Feldman Barrett & Russell, 1998; Phye et al., 2007, p. 108; Russell & Barrett, 1999). Activation is not imaginary but refers to one's physiological state (Russell & Barrett, 1999). The words of pleasure and displeasure which define the dimension of valence exist in all human language (Wierzbicka, 1992) and appear in all cultures (Russell, 1991; Russell & Barrett, 1999). The intensity of affective states may vary based on their context (Phye et al., 2007, p. 108). For example, engagement would be more intense with activated than with deactivated unpleasant affect (Phye et al., 2007, p. 108). The centre of the valence and activation map as a subjective neutral point is where adaptation occurs (Russell & Barrett, 1999). While valence and activation are not emotions per say, they nevertheless are a description for an individual core affective state at a specific moment in time (Russell & Barrett, 1999). While Russell and Barrett (1999) suggests using instruments to yield scores on the valence and activation dimensions; they also advise that instead of focusing on the complex field of emotions, to go beyond the study of emotions and focus on the mechanisms that cause emotions. There are other approaches than the valence and activation dimension that allow for emotional states to be differentiated and categorise affection (Phye et al., 2007, p. 108).

3.6.2 Attribution and Motivation

Individuals search for causes yet few of these causes are often important (Weiner, 1985). Causes and their interpretation might change between people and situations, and over time, however, the meaning or understanding of causes are constant (Weiner, 1985). The properties underlying causes are locus, stability, controllability and perhaps intentionality and globality (Weiner, 1985). These properties cause a variety of affect which include emotions such as anger, guilt, pity, shame, pride, gratitude or hopelessness (Weiner, 1985). Motivated behaviour is presumed to be guided by expectancy and affect (Weiner, 1985).

Locus

The locus dimension represents the distinction between internal-external attribution (See Collins et al., 1973) (Weiner, 1985). This locus dimension pertains to the locus of causality and not control (Weiner, 1985). Hedonic bias where individuals attribute success to themselves and failures to others is well documented (Weiner, 1985). It is reasoned that a person who attributes positive outcome to oneself experiences positive self-esteem or pride whereas attributing negative outcomes experience negative self-esteem (Weiner, 1985). All this demonstrates that there is an explicit factor concerning the self (Weiner, 1985).

Stability

The stability dimension describes whether a cause is stable or unstable (Weiner, 1985). For example, a person might attempt to reproduce a causal structure if a prior outcome was successful or they might alter the causes if a prior outcome was undesired to produce a different one (Weiner, 1985). Hence, stability can influence one's expectancy (Weiner, 1985). The perceived stability of a cause influences the changes in successful expectancy (Weiner, 1985). A stable cause will lead to increased certainty or expectancy (Weiner, 1985). An unstable cause will lead to unchanged certainty or expectancy to be different from the past (Weiner, 1985). As repetition is to be expected from stable causes, their certainty or expectancy will be greater than their unstable counterpart (Weiner, 1985).

Control

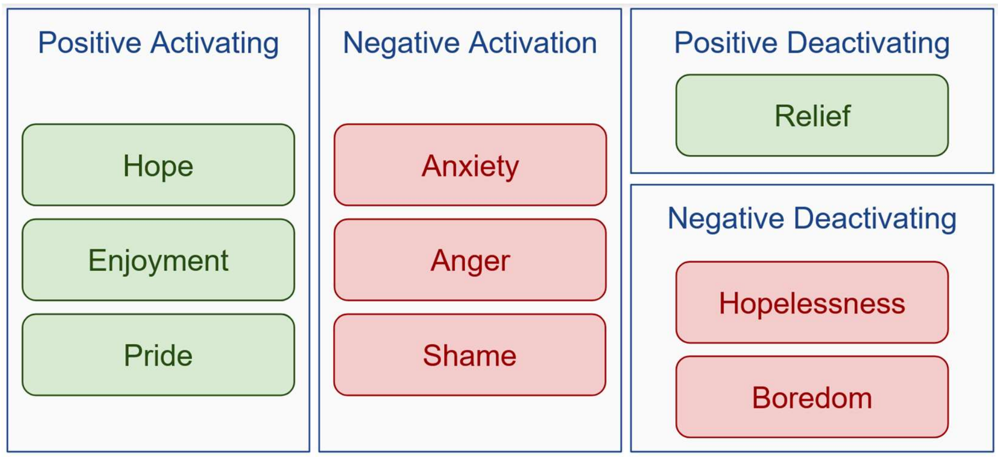
Controllability pertains to one's sense of control over a cause, in contrast to the locus dimension which regards causality (Weiner, 1985). To summarise, the locus dimension is associated with feelings of self-esteem such as pride; controllability is linked to anger, pity, shame, guilt, gratitude; and stability is connected to hopefulness or hopelessness (Weiner, 1985). Other reactions can sometimes be observed (Weiner, 1985). For example, a person may feel guilt while not being responsible or experience emotions without any antecedents (Weiner, 1985). The three dimensions of locus, stability and control do not tell the complete story (Weiner, 1985). The ability and effort required to succeed at activities would not be useful in social acceptance which depend on traits like personality and attractiveness (Weiner, 1985). The relation between the dimensions and affection can change even though it is often presented as not (Weiner, 1985).

3.6.3 Learning and Emotions

Students' emotions are important to their learning, motivation, performance, development and health (Pekrun et al., 2011). Emotions that are prevalent in academia are hope, pride, relief, anxiety, shame, hopelessness, and as activity emotions, enjoyment and boredom during classroom, and anger towards a demand for learning task (Pekrun, 2006; Pekrun et al., 2010; Pekrun et al., 2011). These are the emotions that have been documented to occur frequently in students (Pekrun et al., 2011; Pekrun et al., 2002).

Achievement Emotions

Emotions that are linked to achievements outcomes or activities are defined as achievement emotions (Pekrun et al., 2011). As the control-value theory infers that individuals' appraisals of control and value induces emotions, when an individual feels in or out of control of activities or outcomes that are important to them, they are induced with achievement emotions (Pekrun et al., 2011). Also implied by the control-value theory, when an individual experiences activity emotions during an achievement related activity, these are considered achievement emotions (Pekrun et al., 2011). These achievement emotions can be categorised by affect by the valence and activation dimension (Feldman Barrett & Russell, 1998; Pekrun et al., 2011; Phye et al., 2007, p. 108). Valence can be used to distinguish positive emotions such as hope, pride, relief, and enjoyment from the negative ones such as anxiety, shame, boredom, hopelessness, and anger (Pekrun et al., 2011). Activation can also be used to distinguish activating emotions such as from hope, enjoyment, pride, anxiety, anger; and shame from deactivating emotions such as hopelessness, boredom, and relief (Pekrun et al., 2011). Distinguishing between discrete achievement emotions is important for students as it is connected to their control and value, motivation, learning strategies, self-regulation and academic performance (Pekrun et al., 2011).



This overview classifies (Pekrun et al., 2011) learning emotions based on the semantic structure of affect.

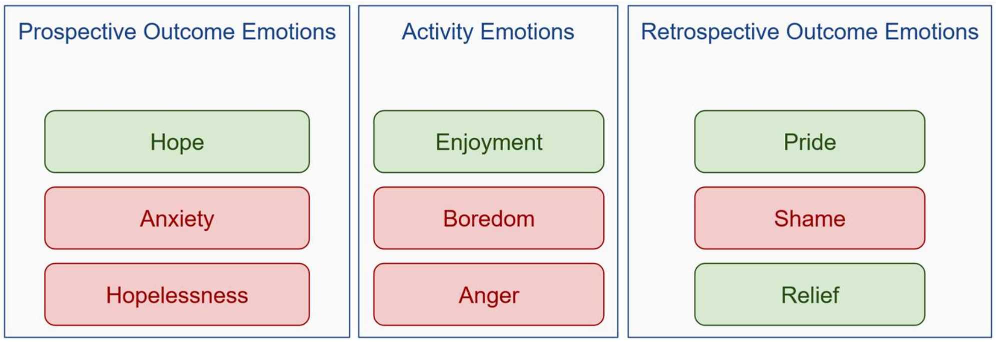
FIGURE 9. LEARNING EMOTIONS BASED ON THE SEMANTIC STRUCTURE OF AFFECT.

Control Appraisal of Emotions

As individuals' appraisals of control affects their emotions, emotions can be defined by said individual's control appraisal (Pekrun et al., 2011). When an individual's actions are expected to produce the desired outcome, for example, academic effort will lead to good grades, it is referred to as action-outcome expectancies and in the educational literature as "academic control" (See Perry et al., 2001) (Pekrun et al., 2011). When an individual is expected to be able to initiate and perform an action, it is called action-control expectancies (Pekrun, 2006) or "self-efficacy expectation" (Bandura, 1977; Pekrun et al., 2011). For example, when a student feels that they had control over an outcome, it is expected that they would feel pride or shame or when a student feels competent to study and interested to learn the content, it is expected that they will feel enjoyment; whereas hope and anxiety are expected to arise from a lack of control and hopelessness from a complete absence of control (Pekrun et al., 2011).

Emotions Relative to the Time of the Activity

These emotions can as well be categorised by their timing relative to the activity with prospective outcome emotions being hope, anxiety, and hopelessness; and activity emotions being enjoyment, boredom, and anger, and retrospective outcome emotions being pride, relief, and shame which respectively occur before, during, and after an activity (Pekrun et al., 2011). There is a distinction to be made between emotional state and trait where a state would be a short lived emotional experience and a trait would be described as a persistent personality trait of an individual, emotions experienced during a series of activities over a long period of time would be located on a continuum between state vs trait (Pekrun et al., 2011).



This overview classifies (Pekrun et al., 2011) learning emotions based on the timing relative to the activity.

FIGURE 10. LEARNING EMOTIONS BASED ON THE TIMING TO THE ACTIVITY.

Learning Motivation and Emotions

Students' motivation, strategy use, learning regulation and other mediating mechanisms are posited to be responsible for these emotions (Pekrun, 1992, 2006), and yet motivation is thought to influence students' emotions with intrinsic motivation based on curiosity and interest, and extrinsic motivation to prevent bad and obtain good outcomes like grades (Pekrun et al., 2011). Under most conditions, positive activating emotions which include hope, enjoyment and pride are believed to encourage intrinsic and extrinsic motivations which in turn have a positive effect on academic performance by enabling flexible learning strategies and self-regulation (Pekrun et al., 2011). On the other hand, negative deactivating emotions like helplessness and boredom are thought to reduce motivation which in turn have a negative impact on the effort required to process information and thus academic performance (Pekrun et al., 2011). Negative activating emotions such as anxiety, anger and shame can reduce intrinsic motivation while invoke strong extrinsic motivation which would be an incentive for students to avoid failure; however, these emotions promote rigid learning strategies such as rehearsal (Pekrun et al., 2011). This implies that student motivation does not require to be strictly positive although for most students the academic negatives will outweigh any beneficial consequences (Pekrun et al., 2011).

3.7 Empathy

3.7.1 What is Empathy?

The concept of Empathy has changed over time (Carré et al., 2013). Among the different definitions for Empathy, there is a consensus that it denotes the imaginative or intellectual comprehension of another person's state of mind or condition (Hogan, 1969). This definition dismisses performance and accuracy of empathy as it only refers to the action of constructing another person's state (Hogan, 1969). For a person to react to other's emotions, they must notice them (Carré et al., 2013; Marshall et al., 1995). Empathy has been considered as the cognitive ability and affective trait that is respectively the capacity to comprehend (Hogan, 1969) or to experience (Bryant, 1982) another's emotions (Jolliffe & Farrington, 2006; Marshall et al., 1995). It is considered a unique ability as it allows one to understand another person's position, as well as their feelings and their causes (Carré et al., 2013). The difference between Identification and Empathy lies within Empathy's ability to distinguish between "self" and "others" (Carré et al., 2013). While important in psychology, it has strong empirical links with prosocial behaviour (Jolliffe & Farrington, 2006). Due to increasing interest in social cognition issues, it has been granted a major interest by researchers not limited to psychopathology (Carré et al., 2013).

3.7.2 Empathy and Morality

Empathy is a key concept in comprehending a wide range of social phenomena including moral development (Hogan, 1969). Empathy and its acquisition are regarded as critical to healthy moral growth (Jolliffe & Farrington, 2006). All approaches to personality that have a focus on interpersonal situations presuppose some form of empathetic disposition, role taking ability, or social sensitivity (Hogan, 1969). Hogan (1969) cites several authors claiming that empathy underlies social interaction and moral development. If a person considers the welfare of others when they contemplate the consequences of their acts, they adopt "the moral point of view" (Hogan, 1969). As such Empathy becomes important within moral development research (Hogan, 1969). An important aspect of moral growth is to have a tendency to understand another's position and have the will to modify behaviour

(Hogan, 1969). However, it can be hard to recognise behaviour adopting the moral point of view as its judgement is very interpretive (Hogan, 1969).

3.7.3 Empathy and Sympathy

Although Sympathy and empathetic responses are sometimes confused, they are different (Carré et al., 2013). Sympathy has also been described in a variety of ways, but there appears to be a general agreement that it entails the assessment of how one feels about another's emotions (Jolliffe & Farrington, 2006). Sympathy and affective empathy both involve an affective reaction to another's perceived feelings (Jolliffe & Farrington, 2006). Their difference lies in that the affection reaction is for Empathy the same as the target (emotion congruence) but for Sympathy it is not the same (Jolliffe & Farrington, 2006). Sympathy and cognitive empathy are both thought to require an understanding of another person's emotional state; however, Sympathy would entail a second assessment of this emotional understanding (Jolliffe & Farrington, 2006). As an example, a person can feel another's sadness (empathy) but may not afford them any sympathy (no sympathy)(Carré et al., 2013; Jolliffe & Farrington, 2006). As Sympathy often stems from Empathy (Carré et al., 2013), in antisocial behaviour studies, it is sometimes unclear to know what is meant when the term "empathy" is used (Jolliffe & Farrington, 2006). Making a distinction between antisocial behaviour, empathy and sympathy would allow for the application of different treatment regarding offences (Jolliffe & Farrington, 2006).

3.7.4 Empathy as a Construct

Empathy as a complex concept has received a lot of attention (Carré et al., 2013; Decety & Svetlova, 2012). Empathy was once assumed to be a single construct, but it is now thought to be made up of different parts (for example, an affective and a cognitive component) (Carré et al., 2013). Empathy was thought as a purely affective concept that was viewed as emotional responses elicited by the other person's emotional state (Jolliffe & Farrington, 2006).

Two components

Empathy has since evolved to account for emotional processing and social interactions (Carré et al., 2013). Empathy has emerged as two components: an affective and a cognitive component (Carré et al., 2013; Jolliffe & Farrington, 2006). The interpersonal reactivity index was later split into affective (personal distress and empathic concern) and cognitive (fantasy and perspective taking) scales (Carré et al., 2013). Having cognitive empathy in addition to affective empathy allows one to further understand the connection between empathy and offending by potentially explaining deficiencies (Jolliffe & Farrington, 2006). For example, in theory, a psychopath's cognitive empathy allows for them to be superficially charming but their lack in affective empathy would explain their willingness to act without other's feeling (Jolliffe & Farrington, 2006). The Basic Empathy Scale (BES) developed by Jolliffe and Farrington (2006) focuses on affective and cognitive factors of Empathy and four emotions of anger, fear, happiness and sadness (Carré et al., 2013). When presented with another person's state of mind, affective empathy is described as the ability to experience an appropriate emotional reaction (Bryant, 1982) whereas cognitive empathy is described as the ability to comprehend another person's emotional condition (Carré et al., 2013; Hogan, 1969). Jolliffe and Farrington (2006) found that intelligence and socioeconomic status reduced the connection between empathy and offending. Carré et al. (2013) developed a variation on the BES scale called the BES-A for Adults. The BES scale and its variant BES-A are valid tools to measure Empathy (Carré et al., 2013; Jolliffe & Farrington, 2006).

Three components

The BES scale does not consider recent understanding of Empathy that it is defined as three concepts emotional contagion, emotional disconnection and cognitive empathy (Carré et al., 2013). While the two-concept model of Empathy was limited by its cognition and affection dimensions, the three-model factor is constituted by the functional and dysfunctional processes and responses in both adults and teenagers (Carré et al., 2013).

- **Emotional contagion** is the emotional replication of another's emotions that is automatic and unconscious from the subcortical structures (Carré et al., 2013). It is the first stage of empathy which is believed to be developed during the preverbal period and that it uses a bottom-up approach (Carré et al., 2013; Decety & Svetlova, 2012; Gyurak et al., 2012). Emotional contagion is both made of a lack of control and a sensitivity to emotions and also a deficit in recognising other's emotions which stems from mislabelling and misidentification (Carré et al., 2013).

- **Emotional disconnection** is a mechanism believed to self-protect individuals from distress, pain and extreme emotions when they are unsustainable (Carré et al., 2013). It acts as a regulator which is controlled by the cingulate and prefrontal cortex and that it uses a top-down approach (Carré et al., 2013). Emotional disconnection could be due to an emotional suppression originating from a clash between a lack of control and understanding others' emotions (Carré et al., 2013). Impulsive behaviour in emergency situations and maladaptive behaviour such as violence in young people is thought to be explained by this suppression (Carré et al., 2013).
- **Cognitive empathy** includes emotional awareness originating from the insular cortex (Decety & Svetlova, 2012) and is thought to be the ability to understand other's position combined with an "orientation towards others" (Carré et al., 2013). It is viewed to be different from automatic identification and emotional contagion (Carré et al., 2013).

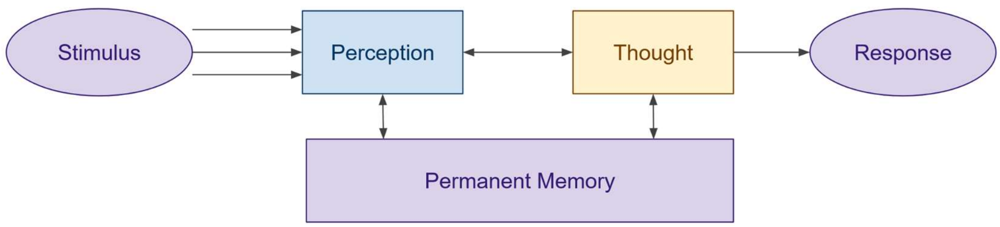
The three factor model due to its delineation allows for better understanding of empathy in emotional and social context (Carré et al., 2013).

3.7.5 Conclusion

A valid and easy scale to measure Empathy would be useful as it is essential to many areas of social psychology (Hogan, 1969). Both the two-factor and three-factor model are both better than the one factor model and appropriate scales (Carré et al., 2013). Empathy is not only a basic skill like recognising emotions or understanding another's perspective but could also rely on cognitive empathy (Carré et al., 2013). As socioeconomic background and parental supervision enhance Empathy, it is important to realise that context populated with high intelligence and introspection such as in theory universities might skew the measurement (Jolliffe & Farrington, 2006). It is always difficult to assess construct validity with personal data (Hogan, 1969).

3.8 Cognitive Style

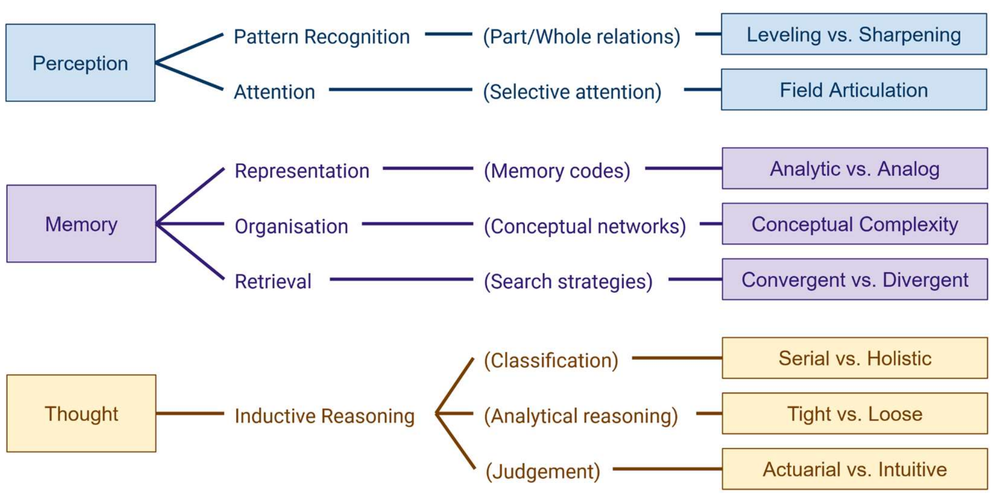
Foucault (2000, p. 299) proposes that instead of investigating what rationale to conform to it is better to understand what the different rationales are. Miller (1987) proposed a model to integrate cognitive style into a cognitive information processing model.



This diagram illustrates Miller (1987) Cognitive Style.

FIGURE 11. COGNITIVE STYLE

This cognitive style framework recognises three major cognitive processes: perception, memory and thought (Miller, 1987).



This diagram presents Miller (1987) Cognitive Style in relation to Information Processing.

FIGURE 12. COGNITIVE STYLE TO INFORMATION PROCESSING

3.8.1 Perception

The perception process registers stimulus from a person's senses which are interpreted by their previous knowledge and is prepared to be used for more complex mental processes (Miller, 1987). For further processing to occur, sensory memory holds data for a short amount of time (Miller, 1987).

Attention

The mental activity concentration due to some incoming stimulus is known as attention (Miller, 1987). Attention describes how a person focuses his mental activity on the task at hand (Miller, 1987).

Selective Attention

Conscious or deliberate attention relies on 'executive' or high order structures to bring attended input into conscious awareness (Miller, 1987). A person who favours deliberate attention might be able to focus their attention at the expense of suppressing or ignoring non-salient cues (Miller, 1987). Whereas, automatic attention involves a pre-conscious mechanism that superficially processes input which allows a person to shift attention by signalling the 'executive' (Miller, 1987). A person with automatic attention would struggle to focus on a task in a distracting setting (Miller, 1987).

Field Articulation

There are two cognitive styles that have been identified in the literature that appear to reflect selective attention to individual differences: 'field dependence-independence' and 'constricted-flexible control' (Miller, 1987; Witkin et al., 1979). Field dependence-independence is the ability to dis-embed in perception which was found to be related to the ability to dis-embed in intellectual activities (Witkin et al., 1979). Constricted-flexibility control is a dimension where the constricted mind shows great difficulty in controlling impulses and a relative inability to use their primary-thinking effectively, and flexibility shows an inhibition to the effect of a need upon cognition (Gardner & Long, 1962).

High articulators analyse stimulus by focusing attention where it is required by the instructions and not responding or ignoring irrelevant or contradictory cues (Miller, 1987). Low articulators respond to and are influenced by non-salient cues (Miller, 1987). They also attend to the most impressive cue as they organise their perceptual field in the simplest way (Miller, 1987). Field articulation can be reasonably interpreted from the differences between analytical and holistic attention (Miller, 1987).

Pattern Recognition

The process of pattern recognition happens when stimulus is compared with information from other memory stores (Miller, 1987). Feature Analysis recognises the distinctive elementary features of a stimuli and the relationship between them (Miller, 1987). Here, pattern recognition relies upon the analysis of stimuli component parts (Miller, 1987). Whereas, prototype matching is more holistic as it will compare the whole stimuli with mental copies of the object or stored templates (Miller, 1987).

Part or Whole Relation

The analytical strategy focuses on detecting differences between the standard memory representation pattern from the experimental one (Miller, 1987). On the other hand, the holistic strategy does not try to search for differences but instead attempts to match corresponding memory representation with test shape (Miller, 1987).

Sharpeners vs Levellers

Sharpeners are sensitive to differences and thus able to maintain changes in stimulus (Miller, 1987). Levellers however tend to not notice changes as they ignore the differences before them (Miller, 1987). Their stimulus relies on preconceptions that they have built (Miller, 1987).

3.8.2 Memory

Miller (1987) discusses the differences in memory in terms of how information is represented, organised and retrieved (Miller, 1987).

Representation

Memory can be represented in many different codes (Miller, 1987). This may be due to a lack of knowledge when to use a skill, a deficiency in meta-strategies, or it could be a matter of style or preference (Miller, 1987). The interaction between style and ability needs to be determined (Miller, 1987). Research on ability and styles may determine how a person adopts a style and how effective they use it (Miller, 1987).

Memory Codes

Memory codes appear to be characterised as verbal-visual dichotomy, however, there are opinions that favour analytical-holistics as being more fundamental (Miller, 1987). While verbal codes support analytical processing (Riding & Anstey, 1982; Riding & Ashmore, 1980; Riding & Calvey, 1981; Riding & Tempest, 1986) analogue codes support holistic processing (Miller, 1987; Riding & Tempest, 1986).

Analytical vs Analog

When investigating interaction between perceptual style (field dependence-independence), memory codes (verbal-imagery) and temperament (extraversion-introversion) (Riding & Tempest, 1986), the relationship between verbal and analytical, and visual and holistic may be more complex than anticipated (Miller, 1987).

Organisation

In regards to organising memory, while permanent memory might be divided into three separate, yet interacting, episodic, semantic and procedural memory (Tulving, 1985), semantic memory is the focus in cognitive style (Miller, 1987).

Conceptual Network

In network theories, semantic memory would be organised in the form of a conceptual network where each node is a concept labelled by a word along with perceptual information and additional semantic giving meaning to a concept (Miller, 1987). Nodes would be linked in a hierarchical manner following the superordinate and subordinate hierarchy of concepts (Miller, 1987). How individuals differ in conceptual networks is the knowledge structures organisation (Miller, 1987).

Differentiation and Integration

The degree of differentiation and integration of a network can show its complexity (Miller, 1987). As **differentiation** relates to how much a homogeneous field is broken down into clear distinguishable components, a system's differentiation degree can be determined by the number of developed subunits and the distance between them (Miller, 1987). A conceptual network with a relatively large number of clearly defined concepts would be highly differentiated (Miller, 1987). **Integration** pertains to how differentiated concepts or units are linked such as into a hierarchy or some other meaningful array (Miller, 1987). A large number of concepts integrated into, for example, a hierarchical organisation would be a complex conceptual structure (Miller, 1987). While novices tend to lack integration, they also had difficulty in differentiating the principle involved in solving problems and thus they were less able to combine principles into superordinate categories (Miller, 1987).

Retrieval

Since semantic memory is organised in the manner of a conceptual network, retrieval could be viewed as a search from one node to another throughout the network (Miller, 1987).

Search Strategies

Search strategies would be dependent by how concepts are associated or linked (Miller, 1987). The activation of these links is not entirely under a person's control (Miller, 1987). The manner in which these links are formed appear to fall into two paradigms (Miller, 1987). The first paradigm involves conscious effort to elaborate concepts' semantics and logically link them by meaning. Whereas the other paradigm seems less "logical", concepts are stored with contextual cues and the linkage is more automatic by connotation, context and emotion (Miller, 1987). Based on the paradigms, there would be individual differences in search strategies for these conceptual networks (Miller, 1987). While one strategy would be a "logical" search, the other which is activated by emotional and situational cues is less controlled and more diffuse (Miller, 1987).

Convergent vs Divergent

The differences in these retrieval search strategies are that of "convergence-divergence" (Miller, 1987). Convergent is defined as when the search narrows down one item to revive information from memory storage (Miller, 1987). This strategy being narrow, deductive, and logical uses sharper search criterion (Miller, 1987). Divergence, however, searches multiple items without any simple, correct nor endpoint. It uses broad and associational strategies, as well as, vague search strategies (Miller, 1987). Individuals who are divergent tend to be more spontaneously flexible and show idea fluidity compared to their converger counterparts (Miller, 1987).

3.8.3 Thought

Reasoning or directed thought, is when current information from the environment with stored information is transformed and manipulated (Miller, 1987). Reasoning would go beyond given information by drawing implications or making inferences (Miller, 1987).

Inductive Reasoning

Deductive reasoning is when these inferences mind a given premise, however, when the inference is a probability derived from experience it is then inductive reasoning (Miller, 1987). Miller (1987) speaks of three different kinds of inductive reasoning: classification; analogical reasoning and judgement (Miller, 1987).

Classification

In classification, conceptual categories are learned and acquired (Miller, 1987).

Serial vs Holistic

Miller (1987) cites the work of many different authors which all converge again towards two orientations. The first focusing-holist orientation is a systematic strategy that follows a route that is both certain and direct (Miller, 1987). Here, as individuals progress through a task, they ensure that it will not require any further attention later by clearing any loose ends (Miller, 1987). The other scanning-partist orientation is a more diffuse strategy that considers many hypotheses and eliminates the hypotheses whose concepts cannot be attained (Miller, 1987). While ambiguity is tolerated, solutions appear slowly from an array of hypotheses (Miller, 1987).

Analytical Reasoning

Analogical reasoning is considered important in specialised areas such as science and arts but also daily life (Alexander, 1984; Miller, 1987). Underlying analogy are four necessary processes of encoding, inferring, mapping and application (Alexander, 1984; Miller, 1987):

- **Encoding** is the identification attribute of a component (Alexander, 1984). It represents for each term in the analogy the identifiable characteristics (Alexander, 1984). For example, a ball is round or bouncy (Alexander, 1984).
- **Inferring** is how a rule determines the relation between adjacent terms (Alexander, 1984). For example, in the analogy feather::bird::leaf::tree, the feather is part of a bird as it grows on it and this is its relationship (Alexander, 1984).
- **Mapping** is when relations are discovered between non-adjacent terms (Alexander, 1984). For example, in the analogy king::prince::queen::princess, king and queen while different genders are both royalty (Alexander, 1984).
- **Applying** is when the derived rules are used to generate a predicted response to complete the analogy (Alexander, 1984). For example, in the analogy bat::ball::hammer::(?), nail would be the best answer as a bat is used to hit a ball, a hammer is used to hit a nail (Alexander, 1984).

Tight vs Loose

For common use, there are two cognitive processes known as literal and deep (metaphoric) analogies (Miller, 1987). Core elements of the base and target situations are mapped to an identity in a literal analogy. In deep analogy, as base and target situations are so dissimilar, the mapping between them is incomplete leading to the identification of the bare essential (Miller, 1987). There is a contrast between literal "tightly" complete mapped and the deep "loose" incomplete mapped metaphoric analogies (Miller, 1987). This contrast can be seen as a stylistic dimension between literal/analytic and poetic/synthetic style (Miller, 1987).

Judgement

Cognitive process models ideally assume that decisions are optimally reached by sampling available information adequately, positive and negative information is treated impartially, and weighing and combining information effectively (Miller, 1987). Alas, as a poor cousin to logical thought, the common heuristic judgement is riddled by cognitive error (Miller, 1987). These errors are also known as biases (Miller, 1987). For example, a person's reasoning could refer to their own personal experience rather than use information from a third party (Miller, 1987).

Actuarial vs Intuitive

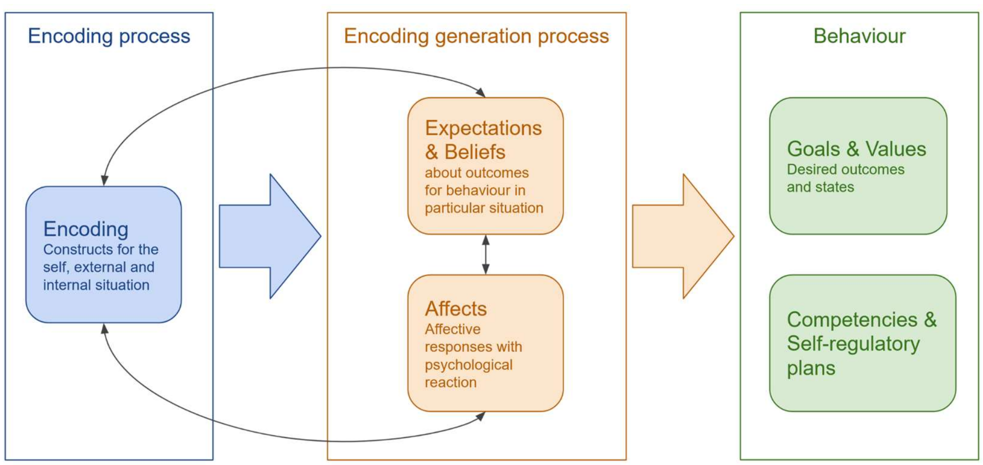
The two forms of judgement actuarial (logical, probabilistic) versus intuitive (reference-point reasoning, non-probabilistic) are aligned with cognitive style (Miller, 1987). The difference between actuarial versus intuitive is analogous with probabilistic versus non-probabilistic thinking (Miller, 1987). A probabilistic when confronted with uncertainty, revises probabilities when new information arises, will show no bias towards or against certain or uncertain events, and will less likely break the normative axioms of decision theory (Miller, 1987). Whereas, a non-probabilistic will tend to place little value on fallible information and not revise probabilities when said fallible information appears, and translate uncertainty into 'yes', 'no' or 'don't know' terms, which violates normative axioms, and is biassed towards opinions with consequences and makes plans on the basis of best guesses (Miller, 1987). While probabilistic and non-probabilistic thinking may appear binary there is no reason for a person to develop a consistent probabilistic thinking style (Miller, 1987).

3.8.4 Conclusion

While there are many different cognitive styles (Hayes & Allinson, 1994), there are two cognitive styles that stand out above all others (Lowik et al., 2017). Lowik et al. (2017) cites Miller (1987) and Nickerson et al. (1985, p. 50) to justify these two types where one is rigorous, deductive, analytical, critical, constrained, convergent, and formal (Associative); and the other is expansive, inductive, synthetic, diffuse and creative, unconstrained, divergent, and informal (Bisociative). In the same citation, Lowik et al. (2017) refers to this oversimplification of cognitive style into Associative and Bisociative types as being useful.

3.9 Cognitive-Affective Personality System Theory

The relation between cognition and affection in behaviour was controversial when it was unknown (Gountas & Gountas, 2007; Im & Ha, 2011). Some argued that affect was a mediator of cognition and behaviour whereas others regarded affect as independent from cognition (Im & Ha, 2011; Oliver, 1993). Under the cognitive-affective personality system theory, individuals encode and categorise situational stimuli that activate cognitive and affective mental states units which generate distinctive complex behaviours (Lee et al., 2010; Mischel, 1973; Mischel & Shoda, 1995). This theory explains the differences in individual behaviours in social behaviours (Lee et al., 2010). It describes the internal chain reaction that occurs inside the mind of a person and represents each mediation state with five relatively stable cognitive affective units which are: the encodings or construal of the individual (of self, other people, situations), expectancies and beliefs (about outcomes and efficacy of the self); affects (subjective values, emotions), goals and values (for the construction and generation for social behaviour); and self-regulatory strategies and plans in the pursuit of goals (Lee et al., 2010; Mischel & Shoda, 1995).



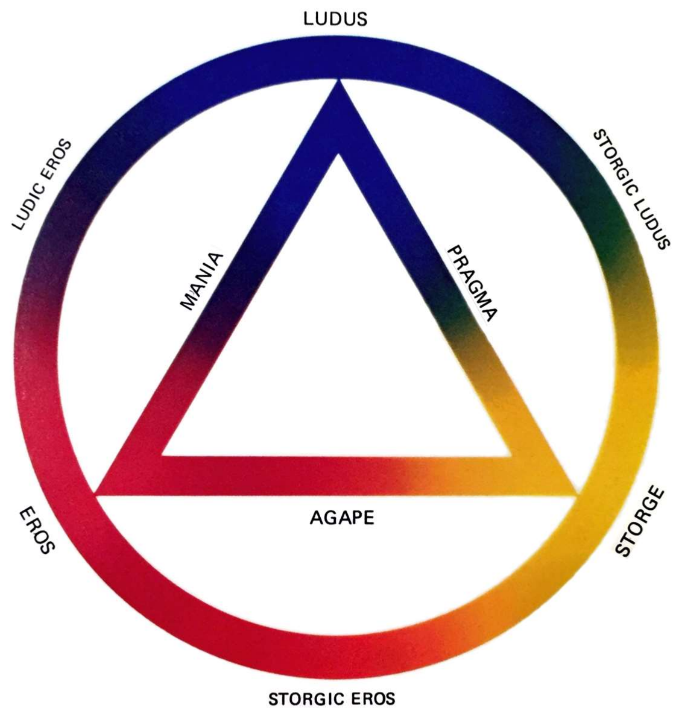
This diagram represents Lee et al. (2010) five cognitive affective units.

FIGURE 13. THE COGNITIVE-AFFECTIVE PERSONALITY SYSTEM THEORY

The encoding unit first transforms external signals (Lee et al., 2010). Then this unit generates and activates the affect unit, and the expectations and beliefs unit which is the cognitive unit (Lee et al., 2010). Ultimately, the interactions between these three units generate behaviour along with goals, values and plans (Lee et al., 2010). While cognition is the mental process of awareness from an immediate understanding of an external stimuli and reasoning of an event or concept, affection is a stable state of mind or disposition which rises and fades after a duration that is formed from understanding, reasoning and judgement (Lee et al., 2010). While there are many studies that posit that cognition is the basis for affection (Lee et al., 2010), Im and Ha (2011) provides results that support the view that affect is independent from cognition. As a framework, this cognitive-affective personality system theory can be used as a basis for an individual's information processing mechanism (Lee et al., 2010).

3.10 The Colour Wheel of Love

As there are many different meanings for the word "love", Lee (1973) set out that there were different types of love where eros, ludus, storge are primary love and mania, pragma, agape are secondary (Lee, 1973). Finally, the tertiary love contained a mixture of all primaries (Lee, 1973).



Lee (1973) the colour wheel of love.

FIGURE 14. THE COLOUR WHEEL OF LOVE

3.10.1 Eros

In Eros, the erotic individual pursues one or more ideal images where they are willing internally to compromise some traits for another as long as in their view the exchange is equal or of greater value (Lee, 1973, p. 36). This ideal image may not be purely physical (Lee, 1973, pp. 36-37). Eros tends to have an all or nothing approach (Lee, 1973, p. 37). Some think that eros is an irrational egotism leading to inevitable disenchantment (Lee, 1973, p. 36), however, Lee (1973, p. 36) testifies that many of his eros respondents would still keep on hoping for an ideal companion.

3.10.2 Ludus

The Ludic individual pursues to game love or in other words, they like to play games (Lee, 1973, p. 58). Ludus like any other game has rules which are when one partner is bored the game is over and neither has any claim over the other (Lee, 1973, p. 58). Ludus can easily be played with multiple people at once however it is best played with a matched partner (Lee, 1973, pp. 59,64). There always have been and always will be people who will game the rules to claim victory at any cost. Unfortunately, this can lead to destruction. Lee (1973, p. 36) does make a point that competent ludic individuals will lay the ground rules explicitly early.

3.10.3 Storge

The storgic individual does not pursue any passion but storge is more of a natural affection without folly nor fever similar to love for a favourite sibling (Lee, 1973, p. 77). Storgic individuals avoid wasting time on romantic displays of affection (Lee, 1973, p. 78). Storge is mediated by activities and common interests which act as a link between individuals (Lee, 1973, p. 80). Storge is a slow-burning love that can survive long periods of dry spells, however, even if it is rarely urgent or hectic, it can still have conflicts or disagreement (Lee, 1973, p. 82). Storge has a low profile thus it is harder to distinguish it from friendship (Lee, 1973, p. 84), nevertheless, Lee (1973, p. 85) draws the following line: “if the respondent believed the experience was love, not simply friendship, I included his experience among my data”. Lee (1973, p. 85) noted that storgic lovers had happier childhood memories than the other love type counterpart.

3.10.4 Mania

Lee (1973, pp. 90-91) describes Mania as chaotic and thriving on conflicts, filled with paradoxes, and transforming revelation. Manic individuals alternate between irrational joyful highs and depressing loneliness downers (Lee, 1973, p. 91). Mania is diagnosed by behavioural analysts as “a paralysis of consciousness”, or “transitory imbecility”, or “melancholic depression” (Lee, 1973, p. 92). Mania can be difficult to distinguish from eros (Lee, 1973, p. 92). While eros is the pursuit of an ideal image, mania is an external madness that preys on the individual (Lee, 1973, p. 93). Manic individuals however, while obsessed by the love of their beloved, appeared to be detached from it which is closer to ludus (Lee, 1973, p. 94). They also had a tendency towards behaviour self-control of expression and display of emotions (Lee, 1973, p. 94). The symptoms for manic individuals are when they feel insecure or lonely, will jump into love for a partner that is an illogical choice (Lee, 1973, p. 97).

3.10.5 Pragma

Pragma is not exciting, unusual, or interesting (Lee, 1973, p. 124). All that pragmatic love needs is a compatibility to suit each other’s practical or basic needs (Lee, 1973, p. 124). Pragma will frustrate individuals who rely on emotional impressions and personal encounters to learn about another person (Lee, 1973, p. 128). A pragmatic individual will produce a list of characteristics, measure them and perform some sort of calculation (Lee, 1973, p. 129). The pragmatic individual has self-control and desires to “settle-down” to a single relationship (Lee, 1973, p. 130).

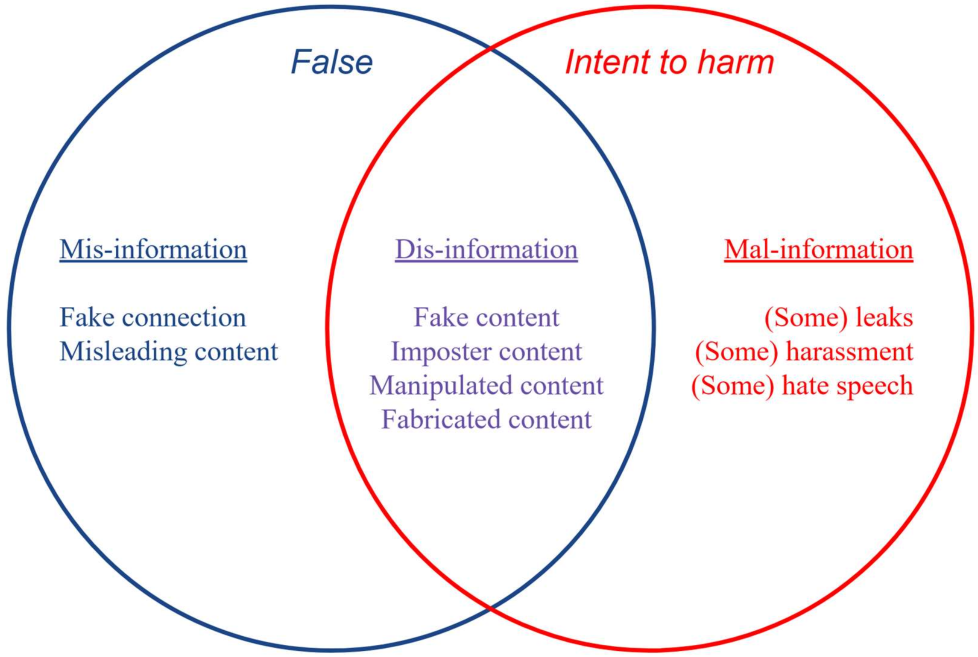
3.10.6 Agape

Agape is completely altruistic, deeply compassionate, without ulterior motives without any strings attached (Lee, 1973, p. 139). Agape can hope for reciprocity even though agape does not expect so (Lee, 1973, p. 139). Lee (1973, p. 140) admits that even he had struggled finding someone who was completely agapic even if it was short term.

3.11 Information Disorder: Misinformation, Disinformation, and Malinformation

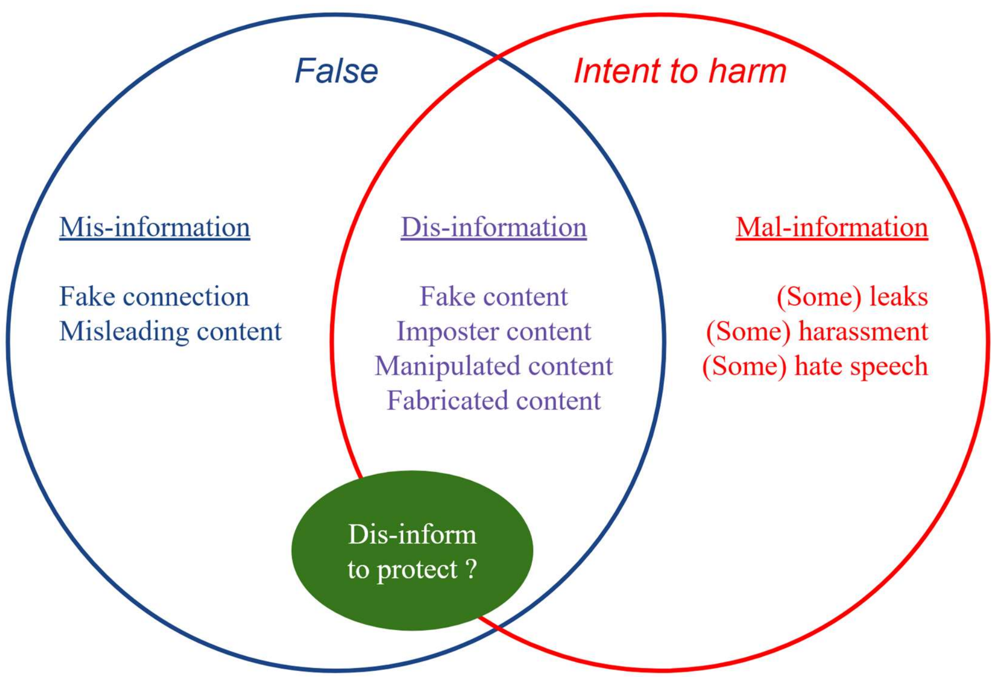
Kandel (2020) calls the sharing of false information irrespective of the intent to harm as information disorder syndrome. There are three categories of information disorders (Kandel, 2020):

- **Disinformation** is information which has been developed with the intent to cause harm while known to be false (Kandel, 2020). Disinformation turns into misinformation when it is shared by others (Kandel, 2020). However, there is a special case to be made for disinformation without intent to harm. A person tells false information that they developed to protect themselves from what they perceive as a potential to harm. It is important to distinguish that the intent to protect oneself and the intent to cause harm to another are not mutually exclusive. A person can tell disinformation to both protect themselves and cause harm to others.
- **Misinformation** is information that is believed to be true even though it is false without the intent to cause harm (Kandel, 2020). The sharing of misinformation is increased by psycho-social factors (Kandel, 2020).
- **Malinformation** is information that is known to be true which is shared to cause harm (Kandel, 2020). An example of malinformation is when someone shares private information that is used to tarnish a person or reputation (Kandel, 2020). Malinformation can sometimes be difficult to verify (Kandel, 2020).



Kandel (2020) Information Disorder

FIGURE 15. INFORMATION DISORDER



Kandel (2020) Information Disorder and including the intention to protect

FIGURE 16. INFORMATION DISORDER WITH INTENTION TO PROTECT

In a virtual environment where information spreads, information disorder is more omnipresent (Kandel, 2020). This includes propaganda but it is not necessarily constraint to politics (Kandel, 2020). While human beings are considered intelligent and wise, even though they have the ability to discern right from wrong, information disorders still affect many of them whether knowingly or unknowingly (Kandel, 2020). The information ecosystem in the digital world is now dividing people rather than connecting them due to said information disorder (Kandel, 2020). In said complex information ecosystem, who owns and how these information disorders are managed and manipulated is very difficult to understand (Kandel, 2020).

3.12 Conclusion

While frameworks cannot answer all questions in existence, they can still have benefits which are better than nothing (Mishra & Koehler, 2006). Mishra and Koehler (2006) cites Darwin:

> *"About thirty years ago there was much talk that geologists ought only to observe and not theorise; and I well remember someone saying that at this rate a man might as well go into a gravel pit and count the pebbles and describe the colours. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service! (Darwin & Seward, 1903, p. 195)"*

Nevertheless, these frameworks can still be used in simulation research method such as ABM.

Chapter 4: Simulation Research Method

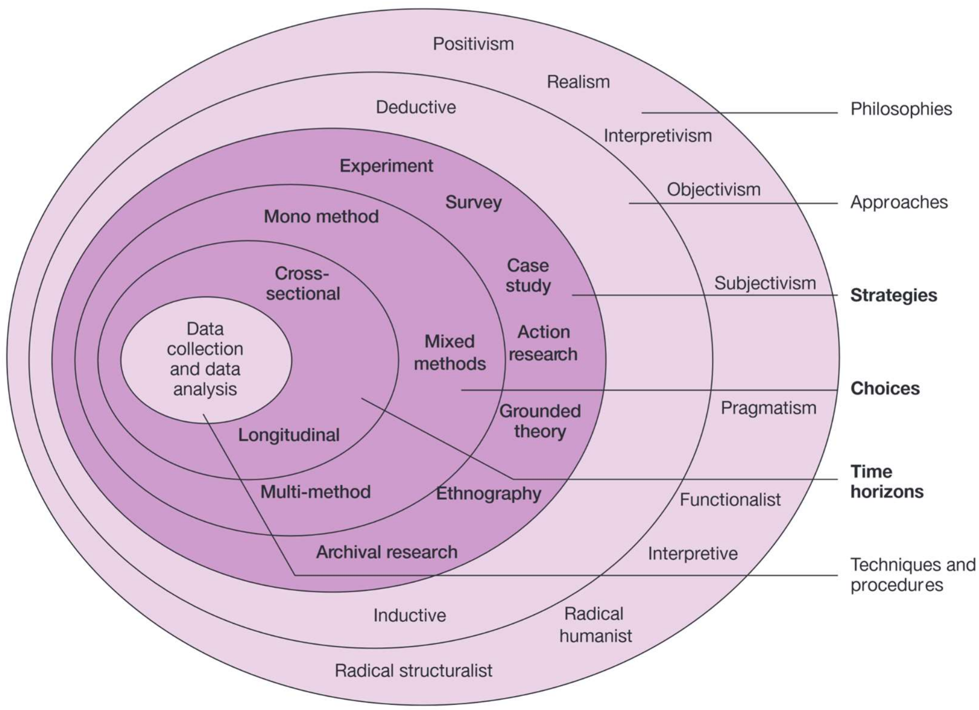
With the advancement of computer technology and the increasing sophistication of algorithms used to model and analyse dynamic systems, simulation has become more significant in recent years (Mujica Mota & Flores, 2020). Simulation methodologies are capable of considering the stochastic character of dynamic systems, as well as the various elements that affect the systems being studied (Mujica Mota & Flores, 2020). In modern times, simulation is commonly employed, either on its own or in conjunction with optimisation approaches, across various industries to address the process of decision-making which involves the exploration of optimal or practical solutions to real-world situations (Mujica Mota & Flores, 2020). Simulation offers numerous advantages, including the ability to explore new policies and procedures without interrupting real system operations, test new systems without committing resources for their acquisition, and manipulate time to compress or expand it as needed (Mujica Mota & Flores, 2020). Simulation is a valuable tool for analysing and evaluating ways to minimise the likelihood of unfavourable results (Mujica Mota & Flores, 2020). Studying the behaviour of a system that changes over time and is influenced by uncertainty can also be accomplished by using a simulation model (Banks & Chwif, 2011; Mujica Mota & Flores, 2020). As there is currently no means to aggregate collective ACAP using individual ACAP, simulation research design offers a solution to this gap.

4.1 Systems to Simulate Organisations

The interactions between individuals or an individual and its environment has an impact which can be felt at different scales and time (Crooks & Heppenstall, 2012). While cognitive ability has been the traditional measurement for task performances, systems might be better at predicting said performances (Hayes & Allinson, 1994; Robertson, 1985). Systems that simulate how individuals make decisions offer researchers a bottom-up approach to human simulation systems (Crooks & Heppenstall, 2012). An artificial society can be grown by modelling people (Crooks & Heppenstall, 2012). Computer models allow for experiments to be set up multiple times using different parameters (Abdou et al., 2012).

4.2 Mixed Methods Research Paradigm

It is tempting to mistakenly believe that one research approach is superior to another (Saunders et al., 2007, p. 116). This would fail to grasp the essence of the matter. They possess superior skills in various areas (Saunders et al., 2007, p. 116). The superiority of one option over the other is contingent upon the specific research question(s) being addressed (Saunders et al., 2007, p. 116). Naturally, in practice, research often does not cleanly fit into just one philosophical topic, as seen in the 'onion' diagram (see figure 17) (Saunders et al., 2007, p. 116).



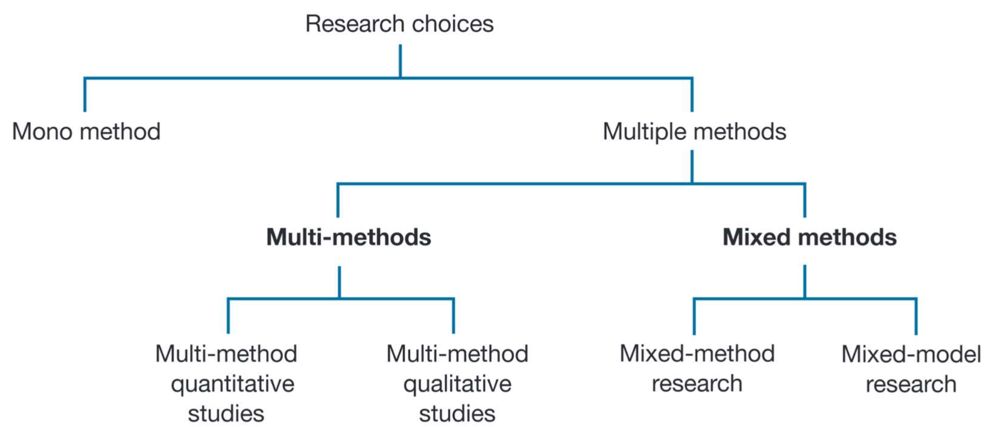
This illustration shows research does not always fit in one topic.

FIGURE 17. THE RESEARCH ONION BY SAUNDERS ET AL. (2007)

In business and management research, the phrases quantitative and qualitative are commonly used to distinguish between distinct approaches for collecting data and procedures for analysing data (Saunders et al., 2007, p. 145). One method of differentiating between the two is the emphasis on quantitative (numbers) or qualitative (words) data (Saunders et al., 2007, p. 145). Quantitative is mostly employed as a synonym for any method of gathering data (such as a questionnaire) or analysing data (such as graphs or statistics) that produces or utilises numerical information (Saunders et al., 2007, p. 145). Conversely, qualitative is mostly employed as a term interchangeable with any method of gathering data (such as conducting an interview) or analysing data (such as organising data into categories) that produces or utilises non-numerical information (Saunders et al., 2007, p. 145). Qualitative data include more than just words; it can also include visual elements like photographs and video clips (Saunders et al., 2007, p. 145).

Saunders et al. (2007, p. 145) use the term "research choice" to describe the decision to integrate quantitative and qualitative approaches and procedures. Quantitative and qualitative methodologies and procedures are interdependent and cannot be considered separately (Saunders et al., 2007, p. 145). When selecting research methods, there are two options: either employ a single data gathering technique and matching analysis procedures (mono method), or use numerous data collection techniques and analysis procedures to address the research issue (many methods) (Saunders et al., 2007, p. 145). Mixed methods refer to the practice of incorporating both quantitative and qualitative data gathering techniques and analysis procedures in a study design (see figure 18) (Saunders et al., 2007, p. 145). It is separated into two categories (Saunders et al., 2007, p. 145). Mixed method research involves the utilisation of both quantitative and qualitative data gathering techniques and analysis procedures (Saunders et al., 2007, pp. 145-146). These methods can be employed either simultaneously (in parallel) or sequentially (one after the other), but they are not combined (Saunders et al., 2007, pp. 145-146). Mixed method research incorporates both quantitative and qualitative perspectives throughout the research methods stage (Saunders et al., 2007, p. 146). Quantitative data are evaluated using quantitative methods, while qualitative data are studied using qualitative methods (Saunders et al., 2007, p. 146). Furthermore, it is common for either quantitative or qualitative methods and procedures to be predominant (Saunders et al., 2007, p. 146). Contrarily, mixed model research integrates both quantitative and qualitative data collection techniques and analytic procedures (Saunders et al., 2007, p. 146). It also mixes quantitative and qualitative approaches during various stages of the research, including the creation of research questions (Saunders et al., 2007, p. 146). This implies that the researcher has the ability to transform quantitative data into qualitative narratives, which can then be subjected to qualitative analysis

(Saunders et al., 2007, p. 146). Alternatively, they can quantify the qualitative data by transforming it into numerical codes, while allowing for statistical analysis (Saunders et al., 2007, p. 146).



Choices of research methods

FIGURE 18. THE RESEARCH CHOICES BY SAUNDERS ET AL. (2007, P. 146)

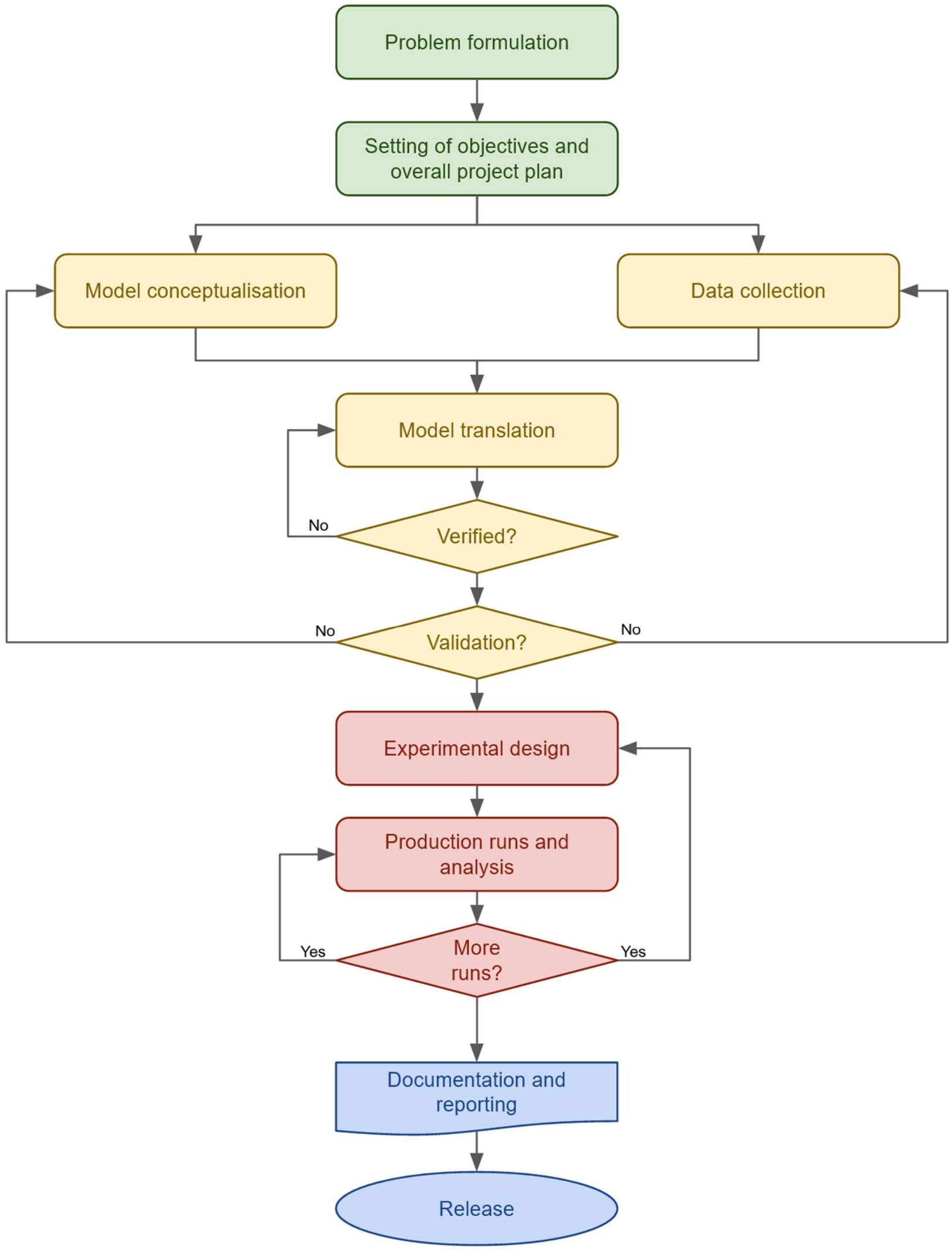
Opting to employ different approaches in a research study offers two significant benefits (Saunders et al., 2007, p. 146). Various methodologies might be employed for distinct objectives in a research endeavour (Saunders et al., 2007, pp. 146-147). Researchers may opt to utilise interviews at the initial stage of exploration to gain insight into the main topics before employing a questionnaire to gather descriptive or explanatory data (Saunders et al., 2007, p. 147). This would instil trust that scholars are actively tackling the most crucial matters (Saunders et al., 2007, p. 147). One additional benefit of utilising mixed approaches is that it facilitates the process of triangulation (Saunders et al., 2007, p. 147). For instance, utilising semi-structured group interviews can serve as a beneficial method for cross-validating data obtained through other techniques, such as a questionnaire (Saunders et al., 2007, p. 147). There is an inherent correlation between the chosen data collection technique and the resulting outcomes (Saunders et al., 2007, p. 147). Essentially, the outcomes will be influenced by the methodologies and protocols employed. The issue at hand is the inherent difficulty in determining the specific nature of that impact (Saunders et al., 2007, p. 147). Given that various approaches and procedures provide distinct outcomes, it is logical to employ diverse methods to counteract the influence of the specific technique used (Saunders et al., 2007, p. 147). This will result in increased trust being placed in the conclusions (Saunders et al., 2007, p. 147).

At this stage, one would wonder (Saunders et al., 2007, p. 147): "How can I determine which data collection techniques and analysis procedures are appropriate for each situation?". There is no straightforward solution (Saunders et al., 2007, p. 147). Saunders et al. (2007, p. 147) promotes the utilisation of creativity and the perception of research as an exceptionally innovative procedure. Nevertheless, it is crucial to establish a distinct research question and objectives for the study, and ensure that the chosen methods are capable of achieving them (Saunders et al., 2007, p. 147). Prior to clarifying the objectives, it is highly tempting to consider the data collection approaches and analysis methodologies to be utilised (Saunders et al., 2007, p. 147).

4.3 Research Design for Simulations

The purpose of the simulation will determine which architecture (design) will have merit (Abdou et al., 2012). Abdou et al. (2012) states very well that the design of every agent has to include mechanisms for receiving input from the environment, for storing previous inputs and actions as a history, for deciding what to do next for carrying out actions and for distributing outputs. Simulation is a potent process that involves multiple phases (Mujica Mota & Flores, 2020). Banks et al. (2005) provides a process to build a simulation model. This process consists of four phases:

1. The first phase is exploration with discovery and orientation and begins with step 1 problem formulation, and step 2 setting the objectives and overall project plan (Banks et al., 2005).
2. The second phase is to build the model and collect data which contains step 3 model conceptualisation, step 4 data collection, step 5 model translation, step 6 verification, and step 7 validation (Banks et al., 2005).
3. The third phase is to run the simulation model and consists of step 8 experimental design, step 9 production run and analysis, and step 10 of additional runs (Banks et al., 2005).
4. The fourth phase of implementation concludes with step 11 documentation and reporting, and step 12 implementation (Banks et al., 2005).



This flowchart presents the steps for a simulation study (Banks et al., 2005).

FIGURE 19. FLOWCHART PROCESS FOR A SIMULATION STUDY (BANKS ET AL., 2005)

4.3.1 Phase 1: Problem Formulation, Setting the Objectives and Overall Project Pan

As every study should start with a statement of the problem, this serves the purpose for step 1 problem formulation (Banks et al., 2005). Step 2 sets the objectives to answer the problem and determines if a simulation is an appropriate methodology to answer the problem and fulfil the objectives (Banks et al., 2005). As the initial statement will probably be vague, as the project moves forwards, this phase will most likely be revisited to clarify and recalibrate at any stage in the project (Banks et al., 2005).

4.3.2 Phase 2: Model Conceptualisation, Data Collection, Model Translation, Verification, and Validation

Phase 2 begins with step 3 model conceptualisation and step 4 data collection which happens in tandem and is then followed by step 5 model translation, step 6 verification, and step 7 validation (Banks et al., 2005). Model conceptualisation requires the abstraction of the features of the problem, the selection and modification of the assumption of the system, and the elaboration of the model until an approximate result is of use (Banks et al., 2005). It is best to begin with a basic model then build complexity on top of it, however, said complexity need not exceed what is required to accomplish the model's purpose (Banks et al., 2005). It is recommended to involve the model user as it would enhance the confidence and the quality of the model's application (Banks et al., 2005). As the model's complexity changes, so can the required data; hence as data collection can take a lot of time, it is necessary to begin collecting data as early as possible along with conceptualising the model (Banks et al., 2005). After the model conceptualisation and data collection is the model translation where the model is programmed in a simulation language (Banks et al., 2005). If the language allows for it, using simulation software can greatly reduce the translation time (Banks et al., 2005). The model translation is followed by verification with assesses if the input parameter and the model's logic structure are correctly represented (Banks et al., 2005). Following is validation which is an iterative process of calibration until the behaviour between model and system are deemed accurate (Banks et al., 2005). As these steps are interrelated, they require a continuous interplay (Banks et al., 2005). Including the model user is critical as otherwise, it can have dire consequences in implementation (Banks et al., 2005).

4.3.3 Phase 3: Experimental Design, Production Run and Analysis, and Additional Runs

Phase 3 executes the simulation and is made of step 8 experimental design, step 9 production run and analysis, and step 10 of additional runs (Banks et al., 2005). Experimental design consists of alternative simulations with decisions of initialisation length, simulation run length, and replication numbers in each run which will be decided based on runs that have been completed and analysed (Banks et al., 2005). Production run and analysis measures the system's design performance of the simulation (Banks et al., 2005). Once the runs have been analysed, a decision is made if additional runs should follow based on the designs of the additional experiments (Banks et al., 2005). A very well-conceived plan is required to experiment with the simulation model (Banks et al., 2005). As the output variables of a statistical experiment are estimates that contain random errors, a proper statistical method is required (Banks et al., 2005).

4.3.4 Phase 4: Documentation and Reporting, and Implementation

The final phase 4 consists of step 11 documentation and reporting, and step 12 implementation (Banks et al., 2005). Documenting and reporting increases confidence in the program and allows the program to be modified by others for future use (Banks et al., 2005). Proper documentation also allows others to experiment with inputs and outputs to learn of the relationships and discover parameters that deliver optimal performance (Banks et al., 2005). One experience with inadequate documentation is usually enough to convince of the importance of this step (Banks et al., 2005). Proper documentation also increases credibility, which acts as a vehicle for certification (Banks et al., 2005). The Overview, Design concepts, Details (ODD) standard is discussed further to address proper documentation. The success of the final step of release in implementation is dependent on every other step in the process, with the most crucial point being step 7 validation and the involvement of the model user (Banks et al., 2005). An invalid model can provide erroneous results, which can be costly and dangerous (Banks et al., 2005).

4.4 Experimental Design

Experimental design refers to the systematic approach of doing research in an unbiased and regulated manner to enhance accuracy and derive particular conclusions related to a hypothesis statement (Bell, 2009). From an alternative standpoint, experimental design aims to reduce ambiguity and strives to eradicate confusion (Bell, 2009). A genuine experimental design hinges on examining the connections between variables (Bell, 2009). The primary objective of fundamental research is to ascertain the existence of a correlation between two variables (Saunders et al., 2007, p. 136). When the experimental design is implemented accurately, it enables the establishment of a causal relationship between the independent variable and the dependent variable(s) (Bell, 2009). Typically, the objective is to determine the impact that a factor or independent variable has on a dependent variable (Bell, 2009). In addition, complex experiments also consider the extent of the change and the relative importance of two or more independent variables (Saunders et al., 2007, p. 136). The primary motivation for experimental design, and arguably the most crucial factor influencing researchers' decision to design and carry out experiments is the ability to analyse the relationship between variables with a high degree of precision and objectivity (Bell, 2009). Typically, one variable, known as the independent variable, is manipulated to gauge its impact on other variables, referred to as dependent variables (Bell, 2009).

The researcher is required to formulate a research question, establish a hypothesis that can be tested, devise methods to control variability in the experimental process, choose or create intervention conditions, sample from a population to assign participants to experimental conditions, and decide on empirical measures and data recording procedures (Bell, 2009). Experiments are frequently used in exploratory and explanatory research to investigate questions concerning the mechanisms and causes of phenomena (Saunders et al., 2007, p. 136).

Undoubtedly, certain business and management research problems will render an experimental strategy unworkable (Saunders et al., 2007, p. 137).

4.4.1 Developing Hypothesis in Experimental Design

An experiment typically involves the following steps (Saunders et al., 2007, p. 137):

- Formulating a theoretical hypothesis.
- Selecting samples of individuals from known populations.
- Randomly assigning the samples to different experimental conditions, such as the experimental group and the control group.
- Introducing planned interventions or manipulations to one or more variables.
- Measuring a small number of dependent variables.
- Controlling all other variables.

An experiment is a deliberate endeavour to construct a controlled setting that rigorously examines a hypothesis, aiming to produce results that closely resemble real-world conditions (Bell, 2009). Prior to conducting an experiment, it is necessary to formulate a testable hypothesis (Bell, 2009). A hypothesis is produced by a meticulous examination and contemplation of previous study findings, serving as a researcher's most informed speculation regarding the occurrence of a phenomenon or the interaction between multiple variables (Bell, 2009). This hypothesis is derived from the selection of a broad topic of interest and the development of a "science question" through a logical examination of theory, past research, previous experimental results, and careful consideration by the researcher (Bell, 2009). The skill of the researcher is a necessary requirement for any scientific endeavour that depends on the formulation of a hypothesis that can be tested (Bell, 2009). Bell (2009) cites Lee (2000) who suggests that hypotheses can be formulated using four separate approaches:

- Formulating a hypothesis using the method of **'analogy'** depends on the ability to recognise the resemblance between distinct yet interconnected facts or processes (Bell, 2009).
- By utilising the process of **'induction'**, a researcher can leverage their scientific and theoretical expertise to construct a hypothesis aimed at assessing the applicability of a specific observation (Bell, 2009).
- **'Deductive'** hypotheses are formulated by utilising a comprehensive comprehension of the mechanisms and characteristics that underpin observable and verifiable phenomena (Bell, 2009).
- When the researcher relies on **'intuition'** to generate hypotheses, they seek what appears to be correct without much prior knowledge to support the reasoning behind the proposed hypothesis (Bell, 2009).

In addition, the success of one's experimental design and their ability to test the stated hypothesis will heavily depend on careful and controlled thought, as well as the deliberate application of reason (Bell, 2009). The hypothesis predicts that there will be an interaction or effect (Bell, 2009). Although there are multiple methods available for formulating a hypothesis that can be tested, doing the actual test necessitates strict adherence to the principles of scientific enquiry (Bell, 2009). Regardless of the amount of time and effort invested in formulating the hypothesis, the researcher must acknowledge that its quality remains uncertain until it is subjected to testing (Bell, 2009). In experimental terms, the researcher aims to accept the alternative hypothesis by disproving the null hypothesis (Bell, 2009). The selection of a research topic and the formulation of a research question (or a science question) are both stimulating and flexible procedures (Bell, 2009). This is the stage where a researcher can freely explore various options that scientific investigation presents (Bell, 2009).

4.4.2 Variables in Experimental Design

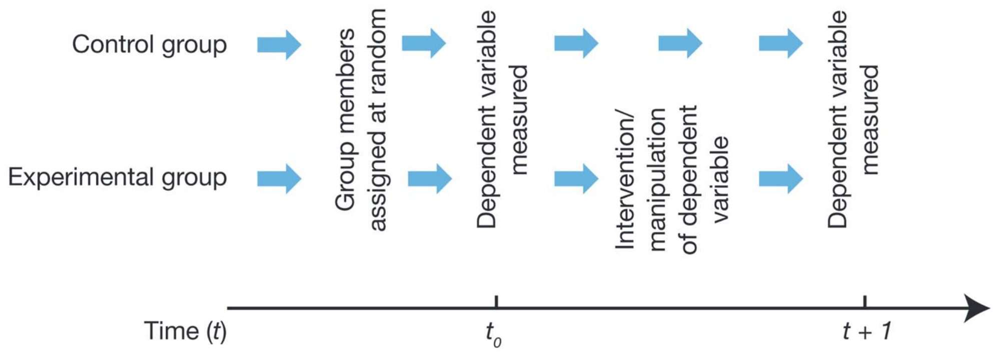
The initial stage in the process of experimental design involves choosing variables, including both independent and dependent variables, that are linked to the phenomena that will be measured (Bell, 2009). Dependent variables are the ones that are measured or observed during the experiment, while independent variables are defined or determined by the researcher before the experiment begins (Bell, 2009). Dependent variables can be measured at many levels: nominal, ordinal, interval, or ratio. In certain cases, researchers have the flexibility to choose the desired level of precision (Bell, 2009). Independent variables, also known as the factor, are assigned specified levels, also referred to as conditions, which are usually nominal (Bell, 2009). When adequately planned, these are expected to have a significant impact on the dependent variable in the experiment (Bell, 2009). Constants are crucial variables in experimental design; they are the aspects in the experiment that remain unchanged throughout its duration (Bell, 2009). By incorporating many components, each having two or more conditions, the research can determine not only the impact of a single factor (referred to as a main effect) but also the interplay between factors (known as interaction effects) (Bell, 2009). However, in some situations, the variable can only be measured in a specific manner (Bell, 2009). The measurements conducted in an experiment can be either direct or indirect. Indirect measurements are based on making inferences between observed data and the phenomena of interest (Bell, 2009). When combining these elements, it is crucial to remember that the most effective method of establishing relationships between variables, especially causal relationships, is to conduct an experiment that enables empirical observation and yields measurable data for comparison (Bell, 2009).

4.4.3 The Intra and Extra Relationship between Experimental Design Cases

The fundamental principles of experimental design involve the allocation of cases to different levels of one or more independent variables (Bell, 2009). If each case is exclusively exposed to a single level of the independent variable, while the remaining cases are exposed to different levels, then the experiment can be classified as a between-subjects or between-case design (Bell, 2009). A repeated measures design is an experimental setup where each case is evaluated at all levels of a manipulated independent variable (Bell, 2009). Repeated measures designs necessitate distinct statistical tests, which necessitate a smaller number of cases/participants to have the same statistical power, and afford the researcher greater control over potentially confounding variables (Bell, 2009). Although a repeated measures design offers significant advantages, there are occasions where a between-subjects design is necessary due to the impossibility or inadvisability of using a repeated measures design (Bell, 2009). Repeating measurements experiments that are impossible may arise when the cases involved possess distinct properties that cannot be kept consistent (Bell, 2009). Unwise situations involve scenarios where being exposed to a certain condition can impact the outcome of subsequent conditions, or in an experiment involving human participants, being exposed to a test condition may lead to learning or provide advantages in other conditions (Bell, 2009).

4.4.4 Experimental Design and Data Sampling

In a typical experiment (see figure 20), two groups are created and participants are assigned randomly to each group (Saunders et al., 2007, p. 136). This indicates that the two groups will have the same characteristics in all significant aspects of the study, except for whether or not they are exposed to the targeted intervention or manipulation (Saunders et al., 2007, p. 136). In the initial group, referred to as the experimental group, a purposeful intervention or manipulation is implemented thereafter (Saunders et al., 2007, p. 136). On the other hand, the control group does not receive any form of intervention (Saunders et al., 2007, p. 136). Both the experimental group and the control group are subjected to this measurement (Saunders et al., 2007, p. 136). This suggests that it is possible to compare the status prior to and following (Saunders et al., 2007, p. 136). According to this comparison, any difference in the dependent variable between the experimental and control groups is attributed to the intervention (Saunders et al., 2007, p. 136).



Classic experimental strategy

FIGURE 20. A CLASSIC EXPERIMENT STRATEGY BY SAUNDERS ET AL. (2007)

The utilisation of census and other population surveys, as well as remotely sensed imagery and other samples, aims to represent the known population or capture a specific moment in time (Bell, 2009). However, these methods may not necessarily provide a representative sample of different times or locations (Bell, 2009). Additionally, the presence of spatial dependence among observations makes it challenging to fulfil certain assumptions associated with traditional stochastic statistical methods typically used for experiment based data collection (Bell, 2009). Additionally, when the sample consists of the entire population, such as census data, it is nearly impossible to determine the data distribution under the null hypothesis (Bell, 2009). Conducting experiments with beneficial therapies may be deemed unfair to people in the control group (Saunders et al., 2007, p. 137). Certain individuals exhibit a lack of willingness to partake in trials, thereby resulting in a potential lack of representativeness among those who do volunteer (Saunders et al., 2007, p. 138). As a result, the experimental approach is frequently employed exclusively on confined groups, such as university students, employees of a certain company, and similar demographics (Saunders et al., 2007, p. 138). The experiment's design constraints typically result in the selection of small and unusual samples, which might lead to issues with external validity (Saunders et al., 2007, p. 138).

4.4.5 Conclusion

Crucial subjects relevant to experimental design encompass hypothesis formulation, implementation of experimental control, precise definition of independent and dependent variables, careful selection and allocation of samples or participants to different conditions, data collection, and appropriate selection of reliable statistical tests (Bell, 2009). Control is a crucial consideration for researchers employing experimental design. In experiments, the researcher selects an intervention linked to the independent variable and regulates the manner in which this intervention is implemented or introduced into the study environment (Bell, 2009). This is a crucial assumption in traditional statistical methods and experimental design (Bell, 2009). Although traditional experimental design incorporates elements such as hypothesis statements, controlled interventions, objectivity, dependent and independent variables, sampling techniques, correlation and causality, measurement, and bias, there are certain aspects of research that have at times necessitated researchers to develop tools that deviate from the principles of experiment-based scientific exploration (Bell, 2009). The link between experimental design, data collection, and statistical analysis is often critical and intimate (Bell, 2009).

4.5 Simulating Knowledge Transfer Special Characteristics

Traditional analytical methodologies are unable to examine this particular aspect, and as a result, they lack the necessary flexibility to offer timely answers in the face of continual system changes (Mujica Mota & Flores, 2020). Frequently, investigations, including those in fields closely linked to business and management like organisational psychology, are carried out in controlled laboratory settings instead of real-world environments (Saunders et al., 2007, p. 137). Simulation-based analysis has gained popularity due to advancements in digital computer technology (Mujica Mota & Flores, 2020). To address capacity challenges, analysts employ several methodologies, including scenario-based EXCEL sheets and in-depth studies using a dedicated simulator to analyse system movements and operations (Mujica Mota & Flores, 2020). In modern times, simulation is commonly employed, either on its own or in conjunction with optimisation approaches, across various industries to address the process of decision-making which involves the exploration of optimal or practical solutions to real-world situations (Mujica Mota & Flores, 2020).

4.5.1 Issues with Simulation Method

As laboratory experimentation is performed outside of the field, it implies that the researcher possesses enhanced authority over elements of the study procedure, such as the choice of samples and the environment in which the experiment takes place (Saunders et al., 2007, p. 137). Although this enhances the internal validity of the experiment, meaning the degree to which the results can be attributed to the interventions rather than any shortcomings in the research design, establishing external validity is likely to be more challenging (Saunders et al., 2007, p. 137). Despite the increasing popularity of simulation, many people tend to overlook the necessary processes and best practices while developing a simulation model and analysing the system (Mujica Mota & Flores, 2020). Laboratory environments, due to their inherent characteristics, are improbable to be connected to the practical environment of businesses (Saunders et al., 2007, p. 137). There are typical challenges that arise when using simulation to analyse dynamic stochastic systems, such as manufacturing, logistics, and supply chain management, among others (Mujica Mota & Flores, 2020). A model can have assumptions that describe how the system operates (Mujica Mota & Flores, 2020). These assumptions are represented using mathematical, logical, and symbolic linkages between the many components of the system (Mujica Mota & Flores, 2020). With the advancement of technology and increased computational capabilities, numerous software programmes have been created to facilitate the construction of simulation models (Mujica Mota & Flores, 2020). Computer programmes have gained significant popularity, often overshadowing the essential procedures needed for a successful simulation project and its ability to bring value to the industry (Mujica Mota & Flores, 2020). Nevertheless, the generalizability of findings from a laboratory experiment to all organisations is likely to be lower compared to an organisation-based (field) investigation (Saunders et al., 2007, p. 137).

4.6 Conclusion

Simulation-based analysis is a potent tool that, when utilised correctly, can provide answers to many enquiries about the system being studied (Mujica Mota & Flores, 2020). Nevertheless, as previously said, it is crucial to effectively execute the process to minimise the likelihood of obtaining impractical or subpar solutions (Mujica Mota & Flores, 2020). One particular characteristic of the problem with recipient ACAP in simulating organisational knowledge transfer in an organisation is that each individual is unique. For example, the degree of time and exertion necessary to discard and acquire new knowledge in place of the old ones is proportional to the extent to which prior knowledge is deeply rooted (Szulanski, 2000), and also knowledge is valuable only if it can be readily accessible when required (Karlsen & Gottschalk, 2004), therefore, time is a property of knowledge transfer that is unique to each individual. There are many other parameters and variables unique to individuals in knowledge transfer. Simulation research design is ideal to research individual ACAP in organisations as it takes into account heterogeneity and outliers. This research requires a simulation method that will model said uniqueness, as well as, heterogeneity and most importantly, outliers.

Chapter 5: Agent Based Modelling

This chapter discusses the method which is ABM in further detail. First, it introduces a discussion about systems to simulate organisations. ABM is then discussed in terms of its origin, human behaviour, benefits, its elements, and limitations. Following this, how to approach ABM in terms of analysis, design, and implementation is then proposed. Role Oriented Analysis and Design for Multi-Agent Programming (ROADMAP) method is then argued as the step for analysing an experiment. Scenario analysis is discussed as a way to bridge analysis and design. The design step with conceptual modelling covers the validation with ODD. Finally, the different means of implementation of an ABM are summarised. This chapter concludes stating that ABM is a suitable method to simulate human behaviours.

5.1 Agent Based Models (ABM)

A model is a simple representation of a system which illustrates how the system operates as clearly as possible (Abdou et al., 2012). Agent technology is a computational approach that enables the independent behaviour of entities within a system to be calculated at specific time intervals using the power of computers (Becu et al.; Mujica Mota & Flores, 2020). ABM is a simulation where different agents perform different actions that produce system wide behaviours and outcomes (Crooks & Heppenstall, 2012). These agents which represent social actors are programmed to react to a computational environment which is modelled to its real-world counterpart (Abdou et al., 2012). ABM as a computational method allows researchers to create, analyse and experiment with models made of agents interacting in an environment (Abdou et al., 2012). With a program being a model, its processes are believed to exist in the real world (Abdou et al., 2012).

5.1.1 Origins of ABM

The first ABM is credited to Thomas Schelling where people and their relevant social interactions were represented by agents and their interactions (Crooks & Heppenstall, 2012). There have been a diverse range of subjects for which ABM have been developed such as: archaeological reconstruction of ancient civilisations (Axtell et al., 2002); understanding theories of political identity and stability; understanding processes involving national identity and state formation; biological models of infectious diseases; growth of bacterial colonies; single-cellular and multicellular level interaction and behaviour; alliance formation of nations during the Second World War; modelling economic processes as dynamic systems of interacting agents; company size and growth rate distributions; geographical retail markets, size-frequency distributions for traffic jams; price variations within stock-market trading; voting behaviours in elections; identifying and exploring behaviour in battlefields; spatial patterns of unemployment; trade networks; business coalitions over industry standards; social networks of terrorist groups, to name but a few (Crooks & Heppenstall, 2012). ABM has also been used to investigate the impact of policy on geographic areas including planning education and simulating crime (Crooks & Heppenstall, 2012). These examples can be constructed as lying on a continuum, from minimalist academic models based upon ideal assumptions, to large scale commercial decision support systems based upon real-world data (Crooks & Heppenstall, 2012).

5.1.2 Human Behaviour in ABM

The perspective of the parts that constitute an ABM is often used to describe it (Crooks & Heppenstall, 2012).

Human Computer Metaphor

Computers have been used as a metaphor for the human brain where the mind is explained in terms of computers (Kennedy, 2012). While this has led to advances in understanding the mind and the brain, it has also led to further debates (Kennedy, 2012). The study of human behaviour has developed AI which aims at replicating human intelligence and cognitive science which try to understand human cognition including emotional, intuitive, rational and erroneous (Kennedy, 2012). In both of these disciplines, techniques and methods have been developed to model human behaviour (Kennedy, 2012).

Human Cognition

Individuals decide what actions to take based on their memory, their current state, and the information they sense from their environment (Kennedy, 2012). These senses include the traditional five senses (seeing, hearing, tasting, touching, and smelling) as well as other senses (temperature, balance, acceleration, internals and pain) and each has a minimum sensitivity, duration threshold and a range (Kennedy, 2012). With all this, individuals still have a limit to their processing, the information they absorb, and their memory even though with language, the knowledge sources and memory is expanded (Kennedy, 2012). Behaviour is driven by a cognitive model which is supported by a cognitive architecture that is a structure and functionality that does not change throughout a simulation (Kennedy, 2012).

Human Emotions

Individuals' personality traits which are somewhat constant during one's life affect their thoughts, emotions and behaviours (Kennedy, 2012). While the combination of these traits leads to individuals being different from one another, they are independent and are spread across populations (Kennedy, 2012). As emotions can lead into long-term mood, they can distort the individual's perception and evaluations, resulting in even more complicated behaviours (Kennedy, 2012). While it is already difficult to classify the impact of emotions on decisions, some decisions are purely emotional (Kennedy, 2012). Hence emotion, intuition and the unconscious may need to be included in the decision making process when representing human behaviour in ABM (Kennedy, 2012).

Human Rationality

People are often thought to behave rationally (Jacoby, 2002; Kennedy, 2012). With the Rational Choice Theory, individuals are assumed to maximise their benefits, minimise their costs and behave logically (Kennedy, 2012). Yet, this rationality is defined by external standard (Jacoby, 2002), with warrant superseding justification (Merricks, 1995; Vance & Eynon, 1998), an individuals' rational is not always absolute and the same. To model an agent's behaviour, their rationale requires knowledge to be represented, absorbed, remembered, and applied (Kennedy, 2012). The "Hierarchy of Needs" (Maslow, 1943) provides a way to represent agent's priorities (Kennedy, 2012).

Human Decision Making

Individuals have different knowledge and abilities (Kennedy, 2012). Their decisions are not a simple rational random selection of different equal options, it can be emotional (Kennedy, 2012). This demonstrates that while the behaviour of individuals can be inconsistent, noisy or unexpected, it is not random even when they try to be there for modelling behaviours based on some uniform random distribution and would be very different from actual behaviour (Kennedy, 2012). Such modelling assumes that people's decisions have no preferences, no memory, no foresight and are consistent (Kennedy, 2012). Luckily, modellers being human should know that models require data or some experience (Kennedy, 2012). Social behaviours require some form of internal modelling of others to understand how to get along with others successfully (Kennedy, 2012). To comprehend the essence of this decision-making process, it is typically feasible to solely observe and quantify the spatial behaviour that arises as a consequence of the decision-making process (Bell, 2009). Societies use statistics to be modelled whereas individual and small groups use the same science for their modelling (Kennedy, 2012). The level of behaviour whether individual, small group or large society must first be decided (Kennedy, 2012).

Human Social

As individuals' behaviour in social context is important in different aspects of everyday life, it has been the subject of many research fields (Kennedy, 2012). Economies and culture are developed from exchanges of goods and services, and information in a social context (Kennedy, 2012). Individuals' behaviour is shaped in two different ways from others (Kennedy, 2012):

1. They imagine other's thoughts, feelings and goals,
2. Their behaviour is influenced by others.

Latané (1981) suggested the following mathematical formula for social influence on an individual (Kennedy, 2012):

$$I = sN^t$$

EQUATION 1. SOCIAL INFLUENCE FORMULA

I (Influence) is the subject's conforming or imitation behaviour percentage, s is the circumstances as a constant, N (Number) is the number of others individuals involved, t is a factor which is almost near half of one and less than one (Kennedy, 2012).

The result from the influence of a group's members on each other is that they either take the position of the group mean, a different position than the mean, the position of an influential group member, or no position from a lack of consensus (Kennedy, 2012). Results produced by groups can be greater than individuals, especially with a group made of diverse people who use appropriate methods when evaluating (Kennedy, 2012). Good collective results did not stem from compromises and or achieving consensus but from the different evaluations from members (Kennedy, 2012). Poor results came from conformity or a lack of independence which stemmed from said compromises and consensus (Kennedy, 2012).

5.1.3 Benefits of ABM

Theoretical

Unknown interconnected processes which often connect potentially infinite amounts of interlinked individual components play out at different space and time scales (Crooks & Heppenstall, 2012). The ability to generate different possible futures instead of modelling strong predictive assumptions provides a technique to explore uncertainty (Crooks & Heppenstall, 2012). As ABM describes the interactions and behaviours in a system, its model can directly incorporate dynamics into a system (Crooks & Heppenstall, 2012). The units that constitute a system can be used to more naturally describe the usefulness of the agent based approach under some of the following conditions (Crooks & Heppenstall, 2012):

1. When the individuals' behaviour is not clearly definable by aggregating rates of transition (Crooks & Heppenstall, 2012).
2. When the individuals' behaviour is complex (Crooks & Heppenstall, 2012). While equations can be used to explain complex behaviour, as the behaviour becomes more complex, so will exponentially the equation to the point it is unmanageable (Crooks & Heppenstall, 2012).
3. When it is more natural to describe a system by its activities than its processes (Crooks & Heppenstall, 2012).
4. When the behaviour of an agent is stochastic meaning that randomness isn't arbitrarily introduced into an aggregate equation, it is instead strategically placed into the ABM (Crooks & Heppenstall, 2012).

As individual objects can be represented in ABM, these objects can be combined in the model to create different scaled phenomena (Crooks & Heppenstall, 2012). As ABM models complex social systems using individual representations, it allows for simple agent based rules to generate or replicate complex social phenomena that are observable (Crooks & Heppenstall, 2012). ABM bottom-up modelling allows local phenomena to be measured and understood on a holistic level (Crooks & Heppenstall, 2012). As any system can be defined in ABM (e.g. a building, a city, a road network, a computer network, etc) and the scale of an ABM is infinite, said scale is determined by the interested phenomena (Crooks & Heppenstall, 2012). ABM provides a useful tool to study effects at multiple scales and levels especially within human social behaviours and individual decision making (Crooks & Heppenstall, 2012).

Practical

Agents based models can be thought of as a laboratory where the environment of the experiment which houses agents with their attributes and behaviour can be altered to observe the repercussions over time over the course of multiple simulations (Crooks & Heppenstall, 2012). ABM has three main advantages over traditional modelling techniques which are that they are flexible especially with models that are geospatial, that they can capture emerging phenomena, and that they provide an environment to study some systems (Crooks & Heppenstall, 2012). An ABM can also be useful to capture emerging behaviour in the following conditions (Crooks & Heppenstall, 2012):

1. When complex behaviour such as adapting and learning is present in agents (Crooks & Heppenstall, 2012).
2. When an agent's behaviour can be drastically altered by other agents or in other words, when the interaction between agents is non-linear, discontinuous, discreet, or complicated (Crooks & Heppenstall, 2012).
3. When agent interaction is a complex and heterogeneous topology (Crooks & Heppenstall, 2012). If global homogeneous mixing is the assumption of the aggregate flow equations, the prediction of a behaviour aggregated from the topology of the interaction network can significantly deviate (Crooks & Heppenstall, 2012).

4. When designing a model with a population that is heterogeneous because agents can be any types of units (Crooks & Heppenstall, 2012). ABM allows specifying agents with degrees of rationality instead of assuming individuals have perfect rationality (Crooks & Heppenstall, 2012). As a stable linear system can be susceptible to large perturbations, in contrast to an aggregate differential equation which smooths out fluctuations, ABM can under certain conditions amplify fluctuations (Crooks & Heppenstall, 2012).

Alternative to Complex Mathematical Equations

ABM allows testing of social theories that are difficult to express as mathematical formulae as it maps problems and its structure more naturally than equation based models could because of how entities are given behaviours and transition rules (Crooks & Heppenstall, 2012). Space, networks or structures combination easily governs the implementation of agents' interaction which for example would be far more complicated using mathematics (Crooks & Heppenstall, 2012).

Flexibility

Along with the ability for agents to move in different directions and velocities, ABM becomes very flexible because of all of its different variables and parameters (Crooks & Heppenstall, 2012). As ABM is a model where agents, from their knowledge of the environment, control their own actions, ABM can simulate complex situations (Crooks & Heppenstall, 2012). When finding an appropriate level of description or complexity, or when the level is unknown, the agent based approach can be used (Crooks & Heppenstall, 2012). Agents' complexity (i.e. their behaviour, degree of rationality, ability to learn and evolve, and rules of interaction) can be fine-tuned and the description and aggregation can be adjusted with the robust and flexible ABM framework (Crooks & Heppenstall, 2012). ABM by definition considers systems as disaggregated with detailed description of many agent attributes, behaviours and interactions with an environment (Crooks & Heppenstall, 2012). Aggregate agents, sub groups of agents, and single agents can be easily experimented with different levels of description coexisting within a model (Crooks & Heppenstall, 2012). In most cases, when in need of a simulation of a system made of real-world entities based on object-oriented principles, ABM is a natural method as agent based is closer to reality than other approaches (Crooks & Heppenstall, 2012).

5.1.4 ABM Elements

An Agent Based Model simulates an environment where agents interact (Abdou et al., 2012). ABM are categorised as individual based models (Crooks & Heppenstall, 2012).

Agent Rules

The behaviour and relationship between agents and their environment will be affected by the rules that govern animate and inanimate agents (Crooks & Heppenstall, 2012). A set of rules can be applied to one to many agents (Crooks & Heppenstall, 2012). Expert knowledge, data analysis, numerical work and published literature can provide the foundation for these rules (Crooks & Heppenstall, 2012). The rules are usually "if-else" conditions which once satisfied then an action is carried out (Crooks & Heppenstall, 2012). As an automata changes its internal characteristics based on the rules that govern its reaction when it processes external inputs, ABM (along with cellular automata) have benefitted from the development of automata (Crooks & Heppenstall, 2012).

Agent Interactions and Space

While an agent is able to interact with another agent or with its environment, it can be ignorant of another agent's actions (Crooks & Heppenstall, 2012). ABM can regulate interactions based on distance and direction which allows action at a distance (Crooks & Heppenstall, 2012). The environment is the space where the agent takes actions with the space being defined as proximity for distance, adjacency for grids, or connectivity for social network (Crooks & Heppenstall, 2012). An agent can be fixed to a location or free to roam (Crooks & Heppenstall, 2012). Its relationship can be from a simple reaction triggered by an external stimulus to achieving a specific goal (Crooks & Heppenstall, 2012).

Agent Behaviours and Time

An agent's behaviour can be synchronous with a set time so that changes occur at the same time or asynchronous where actions are scheduled in reference to a clock or by another agent's action (Crooks & Heppenstall, 2012). Even though time can move in a snapshot (time is discrete), these snapshots may be small enough to emulate real time (Crooks & Heppenstall, 2012). ABM can also use different automata clocks to emulate different timescales for different processes within a single simulation (Crooks & Heppenstall, 2012; Torrens, 2003). Hour by hour social interaction, daily commuting, and long-term economic cycles are examples of processes with different timescales (Crooks & Heppenstall, 2012).

Agent Properties

Agents have, from a pragmatic modelling point of view, many common features (Crooks & Heppenstall, 2012):

- **Autonomy**: Agents are not governed by the influence of centralised control making them autonomous units (Crooks & Heppenstall, 2012). They can process information and make independent decisions (Crooks & Heppenstall, 2012). They can exchange information and interact with other agents over a limited number of situations without affecting their autonomy (Crooks & Heppenstall, 2012).
- **Heterogeneity**: As an agent could represent an individual with attributes, groups of agents are amalgamations of similar individuals (Crooks & Heppenstall, 2012). These groups of agents are spawned from the bottom-up (Crooks & Heppenstall, 2012).

- **Active**: As agents can exercise independent influence, they are active with the following features (Crooks & Heppenstall, 2012):
    - **Pro-active/goal-directed**: Agents will try to achieve goals following their behaviour (Crooks & Heppenstall, 2012).
    - **Reactive/Perceptive**: Agents can be given prior knowledge as a mental map of their surroundings as well as designed to have a sense or awareness of their environment (Crooks & Heppenstall, 2012). This provides them with knowledge of other entities, obstacles, or required destinations within said environment (Crooks & Heppenstall, 2012).
    - **Bounded Rationality**: Rational choice paradigm while being the dominant form of modelling within social science assumes that agent's rationale is perfectly optimised with unlimited access to information, infinite analytical ability and foresight (Crooks & Heppenstall, 2012). In contrast, an agent can be programmed with a 'bounded' rationale which enables them to move towards a goal with inductive, discrete, and adaptive choices (Crooks & Heppenstall, 2012).
    - **Interactive/Communicative**: Agents can extensively communicate with other agents or the environment within a neighbourhood (Crooks & Heppenstall, 2012).
    - **Mobility**: While agents can be fixed, they can also 'roam' the space within a model (Crooks & Heppenstall, 2012). Along with their intelligence and ability to interact, this allows for a lot of potential uses (Crooks & Heppenstall, 2012).
    - **Adaptation/Learning**: Agents can be designed to adapt by altering their state from a previous state which is a form of learning (Crooks & Heppenstall, 2012). This adaptation can be at the individual level where learning alters the distribution of probability for the rules that compete for attention or the population level where learning alters the distribution of frequency for agents that compete for reproduction (Crooks & Heppenstall, 2012).

In social science, the purpose behind an activity is usually indicated by agency which is related to intentions, free will and power to achieve a goal (Abdou et al., 2012). In ABM, Agents have four important characteristics (Abdou et al., 2012):

- **Perception** as in an agent can perceive their environment and other agents in their vicinity (Abdou et al., 2012).
- **Performance** as in agents with a set of behaviours that they can perform like moving, communicating with other agents and interacting with their environment (Abdou et al., 2012).
- **Memory** is where agents record their previous states and actions (Abdou et al., 2012).
- **Policy** is the set of rules that determine given their situation and history what to do next (Abdou et al., 2012).

There will be different types of agents for a simulation; hence, this list is not complete as agents can have features or characteristics that will be more important than others depending on the simulation (Crooks & Heppenstall, 2012).

Agent with Object-Oriented Programming

Abdou et al. (2012) makes the point that Object-Oriented Programming is crucial to agent-based modelling. In programming, while an object is able to store data as attributes and has methods to process said data and interactions with another object, an agent as an object is natural (Abdou et al., 2012). As a class is an abstract specification of an object that usually holds some methods for its activities, when the program is run, objects are instantiated from classes (Abdou et al., 2012). In ABM, classes are designed for each type of agent to retain the agent's past current state with attributes (memory), and these are to observe the agent's environment with methods (perception), and follow rules (policy) to carry out actions (performance) (Abdou et al., 2012).

5.1.5 Limitations of ABM

Hardware

As ABM requires multiple runs with different initial conditions or parameters to assess the robustness of its results, since the parameters space size is the practical upper limit, checking the parameters robustness can be computer intensive and time consuming (Crooks & Heppenstall, 2012). When modelling large systems, ABM's high computational requirements remain a limitation (Crooks & Heppenstall, 2012).

Scoping and Abstraction

An issue that is common to all modelling techniques is that the purpose of the model is only as useful for which it has been constructed (Crooks & Heppenstall, 2012). To serve its purpose, a model needs the right amount of detail and level of abstraction for every phenomenon (Crooks & Heppenstall, 2012). If the model has too much detail, it will be too complicated and have too many constraints, vice versa, and if the model's abstraction is too simple, a key variable might be missed (Crooks & Heppenstall, 2012). To overcome this abstraction issue, the interested phenomenon could give consideration to the level of abstraction needed or specific aspects of a system could examine a series of created smaller models (Crooks & Heppenstall, 2012).

Complexity

Computational and mathematical models can exhibit a wide variety of surprising behaviour that are rare in the real world (Crooks & Heppenstall, 2012). As ABM are sensitive to initial conditions and small variations, predictions which are dependent on these paths could therefore be challenging (Batty & Torrens, 2005; Crooks & Heppenstall, 2012).

Interpretation

The implementation and development of a model for a complex system is complicated because it requires factors that are quantify, calibrate, and sometimes justify and this will in turn complicate the interpretation of simulation output (Crooks & Heppenstall, 2012). Whether the output should be used for qualitative insights or quantitative forecasting is determined by the model's inputs accuracy and completeness (Crooks & Heppenstall, 2012). Crooks and Heppenstall (2012) states that a model's output must be properly interpreted.

5.1.6 Conclusion

While complex system modellers are unlikely to benefit from "laws" present in the physical world, along with the other limitations, to explore systems with complex behaviour, ABM remains a useful tool (Crooks & Heppenstall, 2012).

5.2 Approaching ABM Analysis, Design and Implementation

There is more or less a standardised research process for ABM (Abdou et al., 2012). While the whole process is iterative as ideas are refined and developed, its steps happen in parallel (Abdou et al., 2012).

5.2.1 Reviewing the literature

Existing theories related to the research question can support the model further by illuminating significant factors (Abdou et al., 2012). Comparable phenomena could as well provide similar support (Abdou et al., 2012). Also, any available data should be used for the model (Abdou et al., 2012). The assumptions that are used to build ABM need to be clearly articulated, and justified by available information and supported by existing theories (Abdou et al., 2012).

5.2.2 Identifying the Research Question

The first step is to identify the research question (Abdou et al., 2012). As the model will answer the research question, it is essential that said question is well defined (Abdou et al., 2012). As ABM are used to observe and explain social or macroscopic irregularities that stem from micro interactions between individuals or agents, the research question should be catered to this (Abdou et al., 2012).

5.2.3 Model Design

The following step after specifying the research question, theoretical approach and assumptions is to define the agents in the model and the environment they interact in (Abdou et al., 2012). The attributes and rules of behaviour need to be specified for each type of agent (Abdou et al., 2012). An attribute helps distinguish one agent from another in the model (Abdou et al., 2012). The behaviour of an agent also needs to be defined in different circumstances which can be accomplished using two lists: one showing all the ways an agent can affect the environment including other agents and vice versa (Abdou et al., 2012). The conditions in which the agents react and when the agents act in the environment can be written down (Abdou et al., 2012).

Abdou et al. (2012) informs that an easy way to design reactive agents that respond with an action to stimulus from the environment is to use a production system which has three components:

1. A set of behaviour rules which determine what an agent will do, these rules usually consist of a condition which states when the rules are to be executed and an action which commands the consequences when a rules condition is met (Abdou et al., 2012).
2. A working memory represented by variables that store previous or current states, rules can also act as an action test the state of working memory or insert facts into the working memory (Abdou et al., 2012).
3. A rule interpreter considers each rule, executes those whose condition is true, and performs its actions and repeats the cycle indefinitely. Different rules may be executed because of other rules in the working memory or of the immediate environment has changed (Abdou et al., 2012).

However, there are times when agents must be designed to be capable of learning which means that their internal processing and structure adapt to change (Abdou et al., 2012).

Artificial Neural Networks (ANN) and evolution algorithms (like genetic algorithms) are two common methods to design learning agents (Abdou et al., 2012). As an analogy to nerves in the brain, ANN is made of three or more layers of neurons where one layer is connected to adjacent layers with the first layers accepting inputs from the environment, processing it and passing it onto the next layers and other layers transmitting signals so on and so forth until it reaches the output layers (Abdou et al., 2012). As neurons adjust inputs by negative or positive weights that they receive from previous layers, they sum those weights and pass on the signal to the next layer (Abdou et al., 2012). The back propagation of the error algorithm allows the network of neurons to be tuned so that each input gives rise to a different pattern of outputs which is performed by training the network using known examples and adjusting weights until the desired output is generated (Abdou et al., 2012). ANN can be used to design agents to learn to identify objects like letters, words, pictures and voices (Abdou et al., 2012). Unlike a production system, an ANN can change its response to stimuli based on experiences (Abdou et al., 2012). The alternative to using ANN to design a learning agent is the evolutionary algorithm which uses a population of agents who breed with each other to produce other agents which inherit some feature from their parent averaging and adapting to their environment (Abdou et al., 2012). Both ANN and evolutionary algorithms can be used in the same ABM (Abdou et al., 2012).

Another important point is how the environment should be formed to model the outputs to be displayed to show the macro level regularities (Abdou et al., 2012). Environments are easier to implement as they can be programmed like agents without reacting to their surroundings (Abdou et al., 2012). Another option is to link agents together into a network using relationships as network links to avoid spatial representation(Abdou et al., 2012).

5.2.4 Verifying and validating

Abdou et al. (2012) recommends aiming for at least 100 agents and 30 to 50 runs unless there is a reason to do so otherwise. The standard deviation should be quoted to indicate the variability (Abdou et al., 2012).

Visualisation

Visualisation can help with verification and validation as it conveys the model more transparently, and more clearly and quickly (Crooks & Heppenstall, 2012). As visualisation is one of the best ways to communicate information it is very helpful that ABM is overtly visual (Crooks & Heppenstall, 2012). The dynamics of ABM allows for real time visualisation which has the advantage of showing the aggregates from an individual's micro interactions (Crooks & Heppenstall, 2012). Tools like virtual worlds and game engines offer further visualisation and communication options for ABM (Crooks & Heppenstall, 2012). Furthermore, outcome visualisations may even help evaluate the model's qualitative validity (Crooks & Heppenstall, 2012).

Verification, Calibration and Validation

Even when an abstract model is designed and a proper toolkit and software has been selected, other issues that need consideration will remain, such as explaining how the model works and its verification, calibration and validation (Crooks & Heppenstall, 2012). Crooks and Heppenstall (2012) cites North and Macal (2007) pages 30-31:

> *"Verification is the process of making sure that an implemented model matches its design. Validation is the process of making sure that an implemented model matches the real-world."*

While verification means to test that the logic of the model is behaving as expected (and this should not be taken for granted), validation means how much the model represents the real world which can be seen as the model to data goodness of fit (Crooks & Heppenstall, 2012). Validity should be seen as a degree and not a binary statement as it can have many measures of fit (Crooks & Heppenstall, 2012). Calibration, unlike validation, pertains to adjusting the model to its data using a set of parameters to scale the model's dimensions (Crooks & Heppenstall, 2012). The difference between calibration and validation lies with the parameters that are chosen that are optimal to the performance of the model to its data (Crooks & Heppenstall, 2012). In most ABMs, the data available is usually outweighed by the parameter's assumptions and processes which then impedes on the uniqueness of their estimation when assessing for goodness of fit (Crooks & Heppenstall, 2012). Many simulations also use a random number generator which compounds the difficulty of verification as every run generates different numbers which affects distribution; thus, making debugging crucial (Abdou et al., 2012). Verification and validation have been raised as a concern and limitation of ABM (Crooks & Heppenstall, 2012). A model's confidence and underlying assumption can be increased by allowing others to replicate it by providing the source code, parameters, data and description like Overview, Design concepts, Details (ODD) protocol (Crooks & Heppenstall, 2012).

5.2.5 Implement ABM

The program code can then be developed once all the previous steps have been thought through (Abdou et al., 2012). There are two procedures involving most ABM which are:

- The setup procedure (sometimes referred to as initialisation) that initialises the simulation which at the start specifies the state of the simulation and is executed once (Abdou et al., 2012).
- The dynamic procedure which is executed repeatedly and has agents interact with their environment and other agents using the behavioural rules which in turn, through a series of action-reaction effects, will cause changes in the environment (Abdou et al., 2012). There can be a condition to stop the program in the dynamic procedure (Abdou et al., 2012).

As many simulations are constructed using the same elements, these have been compiled into frameworks or libraries to be used in agent-based programs (Abdou et al., 2012).

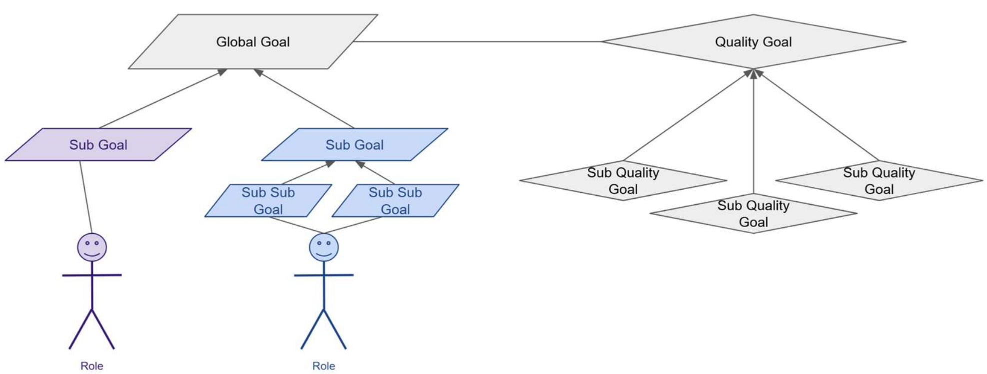
Among the two important practical issues to consider, there is the size of the model where the model needs to be large enough to allow heterogeneity and interaction opportunities and the running of the model where more agents mean longer run times (Abdou et al., 2012).

5.2 Analysis: Role Oriented Analysis and Design for Multi-Agent Programming (ROADMAP) method

Among many of the methods for ABM, there is an unclear separation between analysis and design which takes away flexibility from building an ABM (Kuan et al., 2005). Kuan et al. (2005) proposed a Role Oriented Analysis and Design for Multi-Agent Programming (ROADMAP) method which separates analysis with goal model, role model and social model; and design with agent model, interaction model and the inclusion of an ABM architecture at this stage. Using this method allows for scalability and ease of use (Kuan et al., 2005).

5.2.1 Goal Model

The goal model is the starting point where experts settle on what the system is meant to achieve (Kuan et al., 2005). A goal model contains goals, quality goals (non-functional requirements) and roles (Kuan et al., 2005). While goals and quality goals can have a hierarchy with sub goals and sub quality goals, as roles are determined by the goals, they do not require a hierarchy (Kuan et al., 2005). The components of a goal model do not need to be unique across a system (Kuan et al., 2005).



This diagram illustrates the goal model from (Kuan et al., 2005).

FIGURE 21. GOAL MODEL TEMPLATE (KUAN ET AL., 2005)

TABLE 2. GOAL MODEL NOTATIONS SUMMARY (KUAN ET AL., 2005)

Notation	Representation/Meaning
	Goal
	Quality Goal
	Role
	To show relationship between Goal/ Quality Goal with its related Sub-Goals/Sub-Quality Goal
	To show connection between elements

5.2.2 Role Model

Next follows the role model. A role is a position required to achieve a system requirement and can be decomposed into one-to-many agents (Kuan et al., 2005). Here, the property of a role model is described (Kuan et al., 2005). The role model contains the following fields (Kuan et al., 2005):

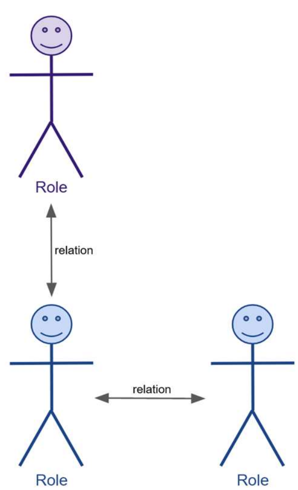
- A name identifying the role,
- A description of the role,
- A list of responsibilities of the role,
- A list of constraints or conditions that the role will have to take into account when executing its responsibilities.

TABLE 3. TEMPLATE TABLE FOR A ROLE MODEL

Role ID	
Name	
Description	
Responsibilities	
Constraints	

5.2.3 Social (or Organisational) Model

The social or organisational model describes the relation between different roles and the rules or policies of their interactions (Garro & Russo, 2010; Kuan et al., 2005). Interactions between members of a group is a type of relation among roles in an organisation (Kuan et al., 2005). These relationships determine how a particular role interacts and fits the system (Kuan et al., 2005).



This diagram illustrates a social or organisational model.

FIGURE 22. SOCIAL MODEL TEMPLATE

The social model should be easy to understand and described by domain experts (Kuan et al., 2005).

5.2.4 Environmental Model

An environmental model depicts environmental entities in a particular domain (Zhi, 2018). It is used to describe holistically the environment of the system (Juan et al., 2002). Juan et al. (2002) points out that open and complex systems often have heterogeneous and dynamic environments.

Although environmental entities are independent from each other, they must be able to interact to fulfil a requirement (Zhi, 2018). If an environmental entity is considered an actor, these interactions are properties that fulfil a purpose which needs to be solved in the modelled system (Zhi, 2018). In other words, the interaction between environmental entities must depict phenomena that the system is designed to investigate. Environmental entities raise phenomena (Zhi, 2018). An environmental entity will have an attribute with a value (Zhi, 2018). Zhi (2018) ultimately describes an environmental entity as Entity|Phenomenon|Interaction→(Attribute→Value).

TABLE 4. TEMPLATE TABLE FOR AN ENVIRONMENT ENTITY

Environment Entity ID	
Name	
Description	
Attributes	
Roles	

As use cases are a first step to problem analysis (Zhi, 2018), environmental modelling can be derived from use cases (Juan et al., 2002).

5.2.5 Agent Model

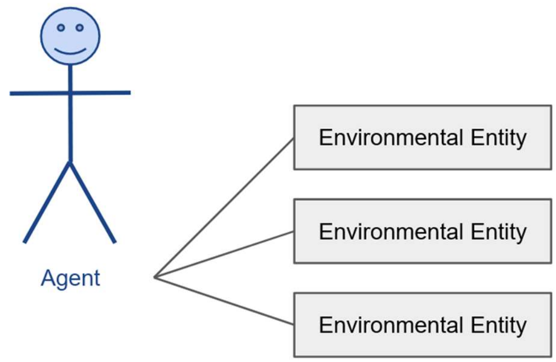
An agent model details the activities an agent's behaviour meant to achieve its goal (Garro & Russo, 2010). These are sets of activities that are either scheduled or triggered which an agent performs to fulfil a goal (Garro & Russo, 2010).

TABLE 5. TEMPLATE TABLE FOR AN AGENT MODEL WITH ITS ACTIVITIES AND ENVIRONMENTAL CONSIDERATION

Agent ID		Agent Name	

Activity Name	
Roles Played	
Functionality	
Precondition	
Postcondition	

Environmental Considerations

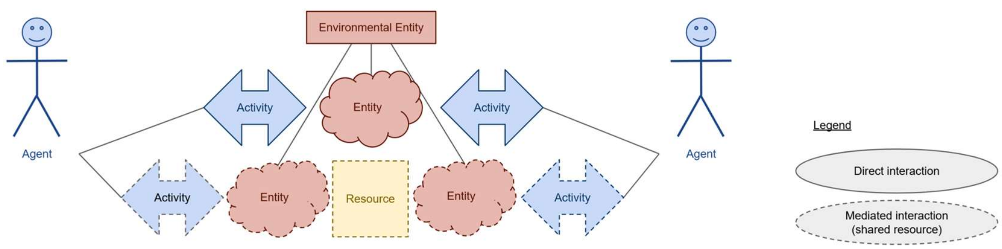


This diagram illustrates an agent model and its environmental consideration.

FIGURE 23. AGENT MODEL TEMPLATE

5.2.6 Interaction Model

The interaction model details the activities in which the agents interact with (Garro & Russo, 2010).



This diagram illustrates an interaction model made of activities which are either direct or mediated.

FIGURE 24. INTERACTION MODEL TEMPLATE

Agents can have either direct or mediated interactions (Grimm et al., 2020). Direct interactions are when an agent directly affects another agent they recognise (Grimm et al., 2020). Mediated interactions are when an agent produces or consumes shared resources which in turns affects other agents (Grimm et al., 2020).

5.2.7 Conclusion

The ROADMAP analysis allows for the preparation of the following steps in implementing an ABM.

5.3 Scenario Analysis

Scenario analysis can be used to model the different paths an individual or group can choose based on parameters, variables, factors, or environmental entities. Scenario analysis presents itself as a suitable method to model an agent's decision making.

This section will first introduce the history of scenario analysis. It will then discuss the different steps in developing said scenarios.

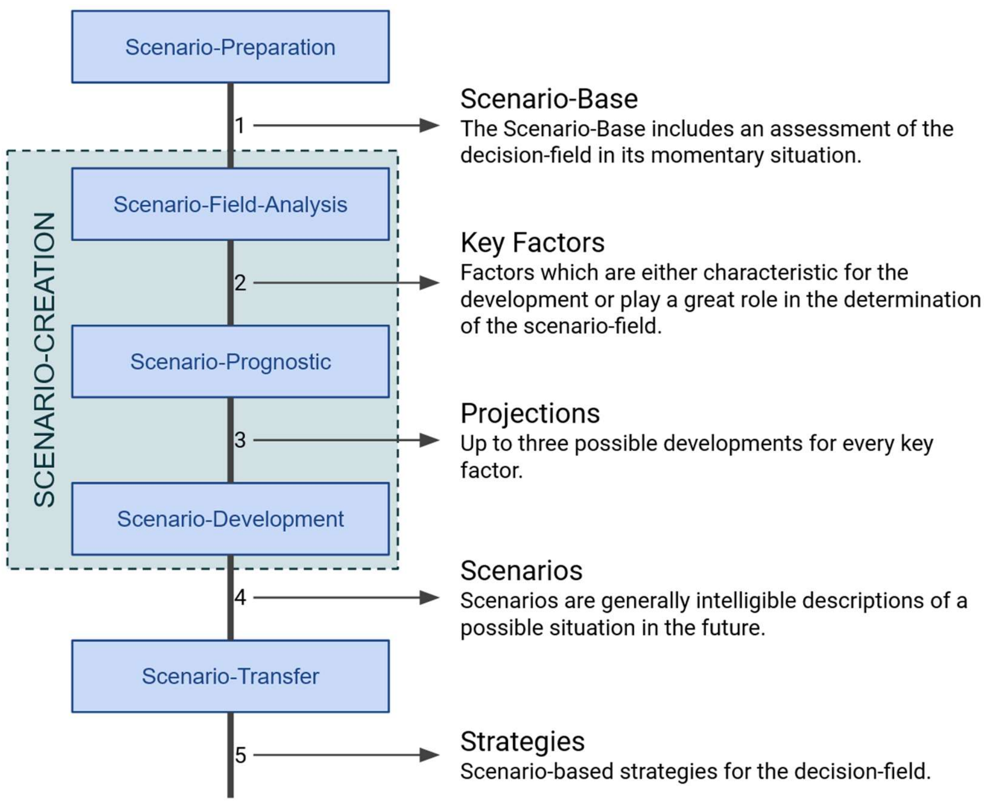
5.3.1 History of Scenario Analysis

From the 1960s and 1970s, scenarios have been built and used in many different ways by decision makers, consultants and researchers (Guenther et al., 2017; van Notten et al., 2003). As scenarios paint many pictures of different possible future outcomes, they assist with limited and strategic thinking (Amer et al., 2013; Guenther et al., 2017). They are not meant to accurately forecast the future but rather bound uncertainties (Guenther et al., 2017; Schoemaker, 1991). In the transition from scenario writing to scenario management, Gausemeier et al. (1998) advises to consider system thinking and multiple futures (Guenther et al., 2017). Upon realising that a business is a subsystem within a system, they are lodged within a complex network of influences, hence, these influence their interdependence, and complexity will play a growing role on said business and thus businesses need system thinking (Gausemeier et al., 1998). Also, in the 1970s, businesses with the belief that the future was predictable improved their prognostic tools so that to better plan, however, with complex dynamics and many uncertainties, businesses were unable to cope with planning fundamentals (Gausemeier et al., 1998). While scenario planning is not a prediction, it is different sights into the future for which business leaders can choose (Gausemeier et al., 1998).

5.3.2 Development Steps for Scenario Analysis

Gausemeier et al. (1998) propose five different phases to develop a scenario:

1. Scenario preparation is where the object of a scenario is decided.
2. Scenario-fields analysis is where key factors of influence are determined.
3. Scenario prognostic is where the projections are developed.
4. Scenario development is where scenarios are developed.
5. Scenario transfer is where the strategic management is applied.



This diagram presents the different phases to managing a scenario by (Gausemeier et al., 1998).

FIGURE 25. PHASES OF SCENARIO MANAGEMENT (GAUSEMEIER ET AL., 1998)

Step 1: Scenario Preparation

Scenario preparation is where the object of a scenario is decided. The scenario project is meant to support decisions, and thus the object of a scenario project is called a decision field (Gausemeier et al., 1998). The present context should determine the decision field before any visions as scenarios are developed (Gausemeier et al., 1998). The ROADMAP goal model can fulfil this purpose.

Step 2: Scenario-Fields Analysis

Scenario field analysis is where key factors of influence are determined (Gausemeier et al., 1998). These factors can be either internal, competitors, environmental or global (Gausemeier et al., 1998). These leads to the creation of different type of scenario (Gausemeier et al., 1998):

- **External scenarios:** Scenarios that concentrate on non-influenceable external factors.
- **Internal scenarios:** Scenarios that concentrate on influenceable internal factors.
- **System scenarios:** Scenarios that include internal and external factors.

Instead of using all identified factors which would create scenarios that are too blurred and complex, selecting key factors which are characteristics or important to the scenario can be achieved with an influence matrix (see table 6) (Gausemeier et al., 1998).

TABLE 6. SCENARIO FIELD ANALYSIS BY (GAUSEMEIER ET AL., 1998)

Influence Matrix Question: "How strong is the impact of factor x row on factor y column?" Scale: 0 = no impact 1 = weak and delayed impact 2 = medium impact 3 = strong and direct impact	Factor a	Factor b	Factor c	…	Active Sum (sum of rows): How strong is the impact of a factor on all other factors?
Factor a		…	…	…	Sum
Factor b	Scale value		…	…	…
Factor c	…	…		…	…
…	…	…	…		…
Passive Sum (sum of rows): How strong is a factor impacted by all other factors?	Sum	…	…	…	

A system grid can also be a useful way to determine key factors on a system's behaviour (see figure 26) (Gausemeier et al., 1998):

- **Impulsive factors** which act as levers as they have been not impacted by many other factors but have a strong impact on the system.
- **Dynamic factors** which can be destabilisers which can stimulate change in the system as they have strong activity and passivity.
- **Reactive factors** which in the short future can be used as indicators.

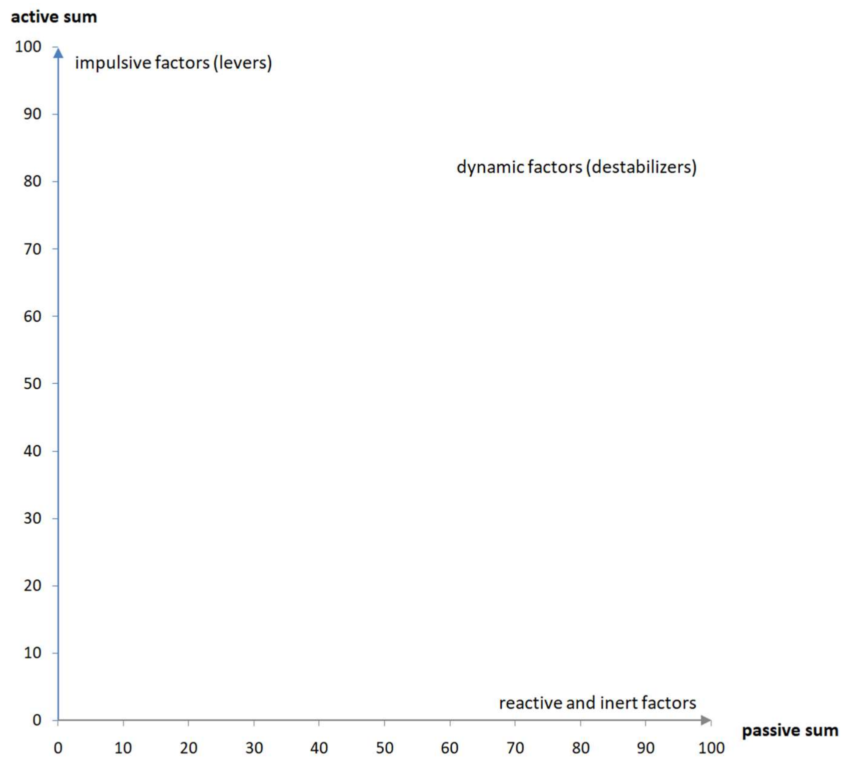


FIGURE 26. SYSTEM GRID (GAUSEMEIER ET AL., 1998)

Finally, other indirect influence analysis such as conventional MICMAC or special indirect influence analysis can also be used (Gausemeier et al., 1998).

Step 3: Scenario Prognostic

Scenario prognostic is where the projections are developed. Usually, three projections per key factor are carried out including the most likely projection as well as the most extreme scenarios which describe “windows of opportunity” (Gausemeier et al., 1998).

TABLE 7. DEVELOPMENT OF A PROJECTION CATALOGUE BY (GAUSEMEIER ET AL., 1998)

Projection Catalogue				
One will find up to 3 possible developments per factor. Those projections are worked out and described "in prose".				
Factor a	Alternative Projections	A: projection description	B: …	
Factor b	**Clear Projection**	A: projection description		
Factor c	Alternative Projections	A:…	B:…	C:…

A projection catalogue (see table 7) lists all these projections with the key factors (Gausemeier et al., 1998).

Step 4: Scenario Development

Scenario development is as per its name, where scenarios are developed. It is made of several steps (Gausemeier et al., 1998):

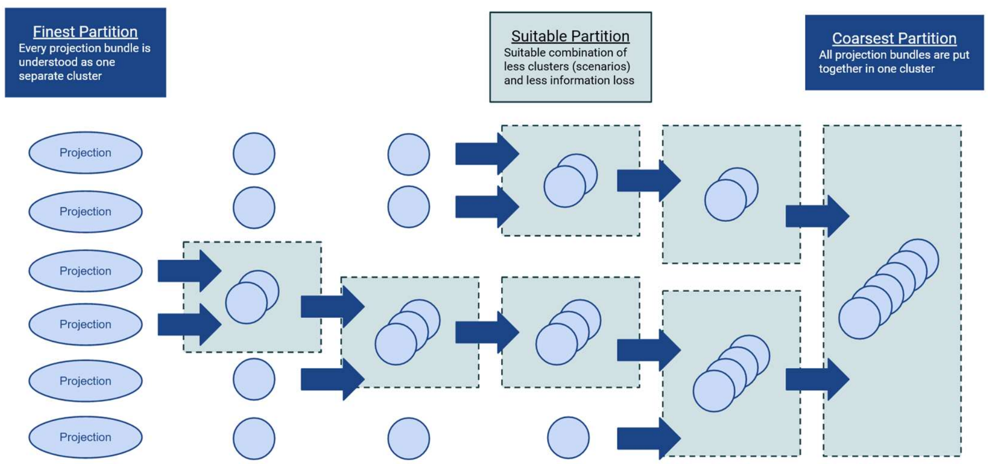
1. The first step is to run a consistency analysis or matrix (see table 8) with all the combination pair projections and filter out contradicting projections (Gausemeier et al., 1998). The remaining uncontradicted combination of project or "projection bundles" (Gausemeier et al., 1998).

TABLE 8. CONSISTENCY MATRIX BY (GAUSEMEIER ET AL., 1998)

<table>
<tr><td colspan="3" rowspan="2">Consistency Matrix
Question: "How consistent is projection x row with projection y column?"

Scale (consistency):
1 = total inconsistency
2 = partial inconsistency
3 = neutrality or independency
4 = consistency
5 = strong consistency</td><td>projection description</td><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td>aA</td><td>aB</td><td>bA</td><td>cA</td><td>cB</td><td>cC</td></tr>
<tr><td rowspan="2">Factor a</td><td>aA</td><td>projection description</td><td colspan="2" rowspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>aB</td><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Factor b</td><td>bA</td><td>…</td><td>Scale value</td><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Factor c</td><td>cA</td><td>…</td><td>…</td><td>…</td><td>…</td><td colspan="3" rowspan="3"></td></tr>
<tr><td>cB</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td>cC</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
</table>

2. The next step is to run a cluster analysis to assign projection bundles to determined scenarios (Gausemeier et al., 1998). At the very beginning of cluster analysis, projection bundles are separate clusters which is known as the finest partition (Gausemeier et al., 1998). During the cluster analysis, projection bundles with similarities are merged into one cluster which comes with a loss of information (Gausemeier et al., 1998). This merging is repeated until there is only one partition known as the coarsest partition (Gausemeier et al., 1998).



This diagram illustrates cluster analysis by (Gausemeier et al., 1998).

FIGURE 27. CLUSTER ANALYSIS (GAUSEMEIER ET AL., 1998)

The "elbow point" is the sudden increase in loss of information which makes it the indication of a balance between less cluster loss and less information loss (see figure 28) (Gausemeier et al., 1998).

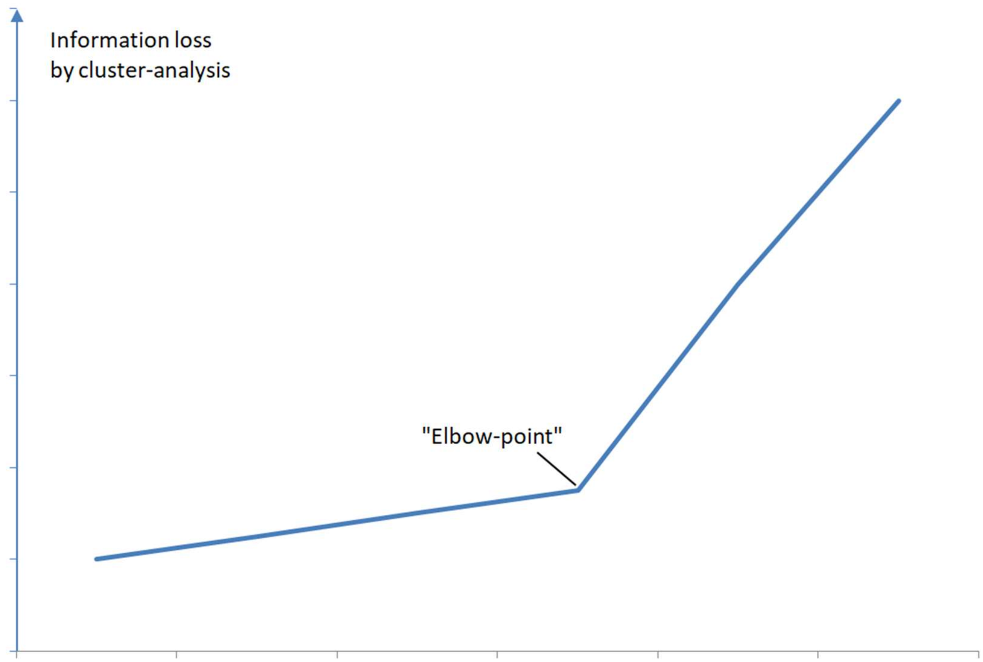


FIGURE 28. PRE-SCENARIO CREATION BY (GAUSEMEIER ET AL., 1998)

3. The last step is analysing each cluster of scenarios and assigning a prosaic description to each one by identifying disruptive factors or events, robustness, and sensitivity analysis (Gausemeier et al., 1998).

Step 5: Scenario Transfer

Scenario transfer is where the strategic management is applied. This begins with the consequence analysis which is again a matrix (see table 9) (Gausemeier et al., 1998). With this consequence matrix, opportunities and threats are discovered for either scenarios or the decision field and based on the decision field's importance and the plausibility, they are valued (Gausemeier et al., 1998).

TABLE 9. CONSEQUENCE MATRIX BY (GAUSEMEIER ET AL., 1998)

Decision field	Scenario field	Scenario 1	Scenario 2	Scenario 3
Decision field component				
Component 1				
Component 2				
Component 3				

- Systematic registration of consequences of scenarios on the decision-field
- Direct derivation of opportunities and threats for the decision-field
- Registration of consequences including actual strengths, weaknesses and the systemic behaviour of similar decision-field components

Once the opportunities and threats have been valued, strategies can be developed which can be applied in the following approaches (Gausemeier et al., 1998; Guenther et al., 2017):

- **Planning-oriented strategy** believes that change can be predicted and therefore strategist can make decisions and take actions in anticipation of said forthcoming change instead of having to wait and react (Gausemeier et al., 1998; Guenther et al., 2017).
- **Responsive or preventive strategy** accepts uncertainty, reacts to environmental change and aims to cope with it (Gausemeier et al., 1998; Guenther et al., 2017).
- **Proactive strategy** accepts many environmental changes are unpredictable but still attempts to anticipate events and take action before the arrival of said change by shaping the environment to unfavoured the likelihood of unwanted changes (Gausemeier et al., 1998; Guenther et al., 2017).

The proactive strategy allows for bundles of actions or "action portfolios" to be set so that when a corresponding scenario matches a "real" future, they can be deployed (Guenther et al., 2017). As only one of these action portfolios can be used which poses a selection problem to decision makers (Guenther et al., 2017). Regarding action portfolios, the common practice is to evaluate their consistency with scenarios holistically using a scale “++” to “--” (Guenther et al., 2017). An agent model with its activity table can fulfil the purpose of an action portfolio.

TABLE 10. TEMPLATE FOR SCENARIOS

<table>
<tr><td>Scenario</td><td colspan="4"></td></tr>
<tr><td>Goal</td><td colspan="4"></td></tr>
<tr><td>Initiator</td><td colspan="4"></td></tr>
<tr><td>Trigger</td><td colspan="4"></td></tr>
<tr><td>Condition</td><td>Step</td><td>Activity</td><td>Agent</td><td>Environment Entity</td></tr>
<tr><td rowspan="2">Sequential</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Parallel</td><td></td><td></td><td></td><td></td></tr>
</table>

5.3.3 Conclusion

The different steps of scenario analysis are conducive to the modelling of an agent's decision in ABM.

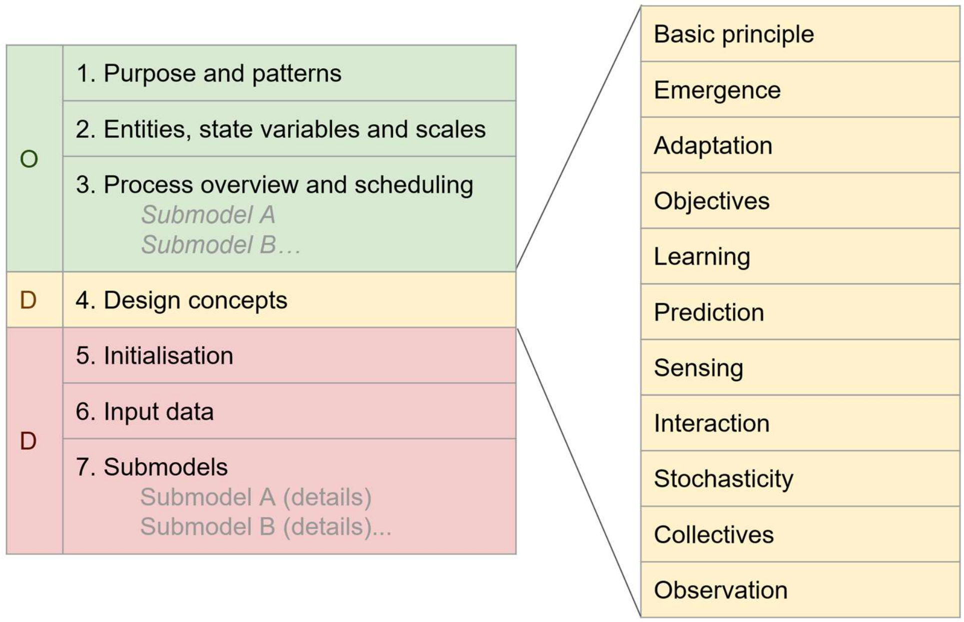
5.4 Design: Conceptual Modelling and Validation with Overview, Design concepts, Details (ODD)

A model's confidence and underlying assumption can be increased by allowing others to replicate it by providing the source code, parameters, data and description like ODD protocol (Crooks & Heppenstall, 2012). ODD is a standard format to document ABM (Grimm et al., 2020). ODD came to be as ABM descriptions were often incomplete, which made reimplementation not possible and violated the scientific requirement that materials and methods must be explained in sufficient detail to allow replication (Grimm et al., 2020). The purpose of ODD was to provide a standard of documentation to facilitate writing and reading an ABM description without being overly technical and facilitate model replication (Grimm et al., 2020). As ODD aims to be used by many different fields, it attempts to facilitate communication across and within disciplines by being less technical (Grimm et al., 2020). ODD model descriptions are based on texts and are meant to be read by humans (Grimm et al., 2020). They can include algorithms and equations (Grimm et al., 2020). These models are independent of the software and hardware to implement the model (Grimm et al., 2020).

5.4.1 ODD Sections Explained

ODD is categorised by "Overview," "Design concepts," and "Details" categories (Grimm et al., 2020). The "Overview" provides an overview, the "Design Concepts" explains how the important conceptual designs were used for ABM, and the "Details" explains all the details for the machine model (Grimm et al., 2020). "Overviews' first section, "Purpose and patterns", briefly describes the model's purpose and the patterns that are used to evaluate the model (Grimm et al., 2020). Its second section, "Entities, state variables and scales", lists the different entities in the model along with their state variables and definition, as well as the model's spatial and temporal resolution (Grimm et al., 2020). Section 3, "Process overview and scheduling", gives an overview of the model's processes with their order, their time, and what state variables are updated (Grimm et al., 2020). As all these belong to the "Overview", the details are specified in as its name suggests "Details" (Grimm et al., 2020). "Design concepts" only has one section, Section 4, "Design concepts", which includes 11 concepts important for designing the

ABM model (Grimm et al., 2020). This section explains the model's designs and the reason it was designed the way it was (Grimm et al., 2020). "Details" contains the final three sections that are Section 5, "Initialisation", Section 6, "Input data", and Section 7, "Submodels", which contains the details of the model with its rationales and allow in principle to reimplement it (Grimm et al., 2020).



This diagram presents the different sections and subsections for the ODD standard (Grimm et al., 2020).

FIGURE 29. ODD STANDARD WITH SECTION AND SUBSECTIONS (GRIMM ET AL., 2020)

1. Purpose

"Overviews" first section, "Purpose and patterns", briefly describes the model's purpose and the patterns that are used to evaluate the model (Grimm et al., 2020). The purpose should be a simple clear statement explaining the "purpose" underpinning the development of the model (Grimm et al., 2020). Identifying which general type of purpose such as prediction, explanation, description, theoretical exposition, illustration, analogy, and social learning is before declaring the purpose can be useful (Grimm et al., 2020). The patterns detail the criteria used to make its purpose real enough (Grimm et al., 2020). These should be observations made at the micro or macro level that are thought to be influenced by the same variables, processes and other items that are crucial for the model's purpose (Grimm et al., 2020). The goal model provides the foundation for the purpose and patterns.

2. Entities, Variables, and Parameters

The second section, “Entities, state variables and scales”, first lists the different entities in the model and then lists their state variables (sometimes referred to as “attributes”) and definition, as well as the model’s spatial and temporal resolution (Grimm et al., 2020). There are several different types of entities which should be listed (Grimm et al., 2020):

- **Spatial units** which in spatially explicit models are entities that show variation in condition over space (Grimm et al., 2020).
- **Agents or individuals** for which in an ABM each agent should be described separately (Grimm et al., 2020).
- **Collectives** if the model has collectives that are shown to have behaviours and variables of their own (Grimm et al., 2020).
- **Environment** entity should be a single entity that represents the environment, the time of the simulation, and any global variables (Grimm et al., 2020).

TABLE 11. TEMPLATE TO LIST OF ENTITIES

Name	Description

State variables which are used to distinguish one entity from another and may change over time would include descriptions of their characteristics which include (Grimm et al., 2020):

- What does the variable represent and does it have units?
- Does the variable not change in time (static) or does it change in time (dynamic)?
- Is the variable a type such as an integer, a text string, a floating-point integer, a set of coordinates, or a Boolean?
- Does the variable have a few discrete values, a limited numerical range or any value at all?

TABLE 12. TEMPLATE TO LIST OF VARIABLES

Entity	Variable	Description	Units	Dynamic or Static	Type	Range

The final step is to describe the spatial and temporal scale of the model or in other words, the total amount of time and space, and the duration of time steps and the size and shape of spatial units in real terms (Grimm et al., 2020).

3. Process Overview and Scheduling

Section 3, "Process overview and scheduling", gives an overview of the model's processes with their order, their time, and what state variables are updated (Grimm et al., 2020). ABM can emulate different timescales using different clocks for different processes in a single simulation (Crooks & Heppenstall, 2012; Torrens, 2003). An agent's behaviour can be synchronous so that changes occur at the same set time or asynchronous where actions are triggered either by a clock or by another agent's action (Crooks & Heppenstall, 2012). Here, the schedule of the model should specify the order of processes to execute at what time step (Grimm et al., 2020). Grimm et al. (2020) recommends using actions which they define as: "An action specifies (1) which entity or entities (2) execute which process or behaviour that (3) changes which state variables, and (4) the order in which the entities execute the process." Actions can be hierarchical and those that are complex should be kept simple and detailed in Section 7 Submodels (Grimm et al., 2020).

4. Design Concepts

“Design concepts” only has one section, Section 4 “Design concepts”, which includes 11 concepts important for designing the ABM model (Grimm et al., 2020). The purpose of this section is not to detail what the model does nor to replicate it but to describe the model within a common conceptual framework to illustrate the developer’s reasons and rationales (Grimm et al., 2020). The 11 concepts for these sections are basic principle, emergence, adaptation, objectives, learning, prediction, sensing, interaction, stochasticity, collectives, and observation (Grimm et al., 2020).

Basic Principles

The basic principles section describes the basic ideas, theories, hypothesis, and modelling approaches of the system and context, and agents, how they relate to each other, and what field do these originate from (Grimm et al., 2020).

Emergence

ABM simulation is used to observe the emergence of phenomena from agent behaviour in a simulation (Crooks & Heppenstall, 2012; Grimm et al., 2020). As scenarios establish how the simulation is set up (Garro & Russo, 2010), different scenarios can be applied to observe different “what if ?” situations (Johnson & Sieber, 2009). Traditional differential equation approaches only provide a snapshot as they do not consider heterogeneity and differences in individuals (Guenther et al., 2017). As an agent based model can model entities at the micro-level, it can overcome such limitations (Guenther et al., 2017). Thus, the scenario analysis can be used to map the different options linking them to parameters, variables, factors, or environmental entities which can then be acted by agents.

Adaptation

Adaptation distinguishes agents' adaptive behaviours or in other terms, what stimuli affects which decision an agent makes (Grimm et al., 2020). This should include description of behavioural components such as the agents' different alternative choices, the internal and environmental variables that affect the decision, and whether a decision is "direct objective seeking" or "indirect objective seeking" which should be further defined in the next section of objectives (Grimm et al., 2020).

Objectives

The objective section is where the objective measurements of agents' actions working towards a goal is defined (Grimm et al., 2020). Objectives can either be "direct objective seeking" which is ranking alternatives by measuring how close each is to accomplishing an objective or "indirect objective seeking" where agents simply follow rules that reproduce observed behaviour (Grimm et al., 2020). If agents' behaviours are modelled to increase their success at achieving a goal, the measurements, their representations, and their calculations need to be explained (Grimm et al., 2020). Agents can also have objectives that serve the collective instead of themselves (Grimm et al., 2020).

Learning

Unlike adaptation which is how variables change over time, learning is about how an agent and their decision-making method such as an algorithm or its parameters are as a consequence of their experience (Grimm et al., 2020). While learning can require memory, not all learning will use memory (Grimm et al., 2020).

Prediction

Successful decision-making and ABM adaptation modelling requires prediction Budaev et al. (2019); (Grimm et al., 2020). Grimm et al. (2020) mentions that Railsback and Harvey (2020) discuss in detail modelling difficult decisions for agents. When estimations of decisions' consequences and conditions in the future explicitly determine agents' learning or adaptation, this is referred to as "explicit prediction" (Grimm et al., 2020). In most other cases, when future decisions' consequences are implied or have hidden assumptions, this is called "implicit prediction" (Grimm et al., 2020).

Sensing

Sensing represents what information an agent "knows" and how this affects their behaviour (Grimm et al., 2020). The sensing process models how an agent acquires information, some variables' values, and even uncertainties (Grimm et al., 2020). The sensing section includes the variables an entity senses and explicit declaration of an agent's state variable that is assumed to affect its behaviour (Grimm et al., 2020).

Interaction

Interaction sections depict interactions as local instead of global (Grimm et al., 2020). The interaction model from ROADMAP analysis can be used here.

Stochasticity

The stochasticity section describes the use of random numbers in the model where variation occurs (Grimm et al., 2020). There are three common uses for stochasticity (Grimm et al., 2020):

1. **Initialisation:** First common usage is in the initialisation to insert variability (Grimm et al., 2020). At the start of an ABM simulation, a pseudorandom number generator can be used to set the initial values of some of the agents' variables (Grimm et al., 2020).
2. **Simplification (assumption):** Second common usage is when a sub-model is assumed to be partly stochastic so that it can be simplified (Grimm et al., 2020).
3. **Mimic behaviour frequency:** Finally, stochasticity is used to mimic agents' behaviours alternatives with the same frequency as in the real world (Grimm et al., 2020).

Collectives

This section describes groups or collectives that are affected by or affect agents (Grimm et al., 2020). Collectives can either not have variables or behaviours, or they can explicitly have state variables or behaviours (Grimm et al., 2020).

Observation

Observation described how to collect and analyse information from the simulation and not how experiments and analysis are run (Grimm et al., 2020). This section can be used to tie back into the purpose from section 1 (Grimm et al., 2020). Observation can also describe statistics along with how they were summarised (Grimm et al., 2020). As modellers are concerned with how the simulation results compare to the real world, some of them may also simulate the data collection (Grimm et al., 2020). While this attempts to reproduce uncertainties and biases in ABM, it is still possible to observe accurate and unbiased observations (Grimm et al., 2020).

5. Initialization

Initialization describes how entities and how many of each kind with their initial variable values are created before the simulation begins (Grimm et al., 2020).

6. Input Data

Input data often drives partially the models' dynamics or in other terms, the environment or simulation is described or affected in a temporal sequence by the values of variables or events (Grimm et al., 2020). Input data is commonly used to represent environment variables which change over time (Grimm et al., 2020). As input data usually contains values that have been seen in the real world, the statistical qualities remain realistic (Grimm et al., 2020). However, input data can be generated using external models and represent external events (Grimm et al., 2020). The origin, uncertainties, biases, and limitations must be documented and explained to fully justify results and avoid misuse of a model (Grimm et al., 2020).

7. Submodels

This section describes any sub-model that was cited but not described in section 3 process overview and scheduling, and section 5 initialisation. Ideally, for each sub-model there should be a subsection.

5.4.2 Limitations

For ABM that are non-trivial, ODD can be very long (Grimm et al., 2020). Especially for models with large complex mathematical models, ODD can easily be 5 to 10 pages long due to the detail contained in the documentation (Grimm et al., 2020). As the hierarchical structure of ODD causes a lot of redundancy in the documentation, it results in lengthy documentation (Grimm et al., 2020). This can lead to the author summarising only a description of the ODD to fit their model into an article (Grimm et al., 2020).

5.4.3 Conclusion

Providing the rationale for the model's design can increase its credibility by showing that the designs have been carefully thought of, and it encourages reuse of a model (Grimm et al., 2020). ODD documentation not only allows for the design of an ABM but it also acts as a means for validation.

5.5 Data Collection

Garbage-In-Garbage-Out (GIGO) is a fairly common concept in computer sciences (Banks et al., 2005). If the data that is inputted is poor, the output of the simulation will also be poor regardless of how valid the structure of the model is (Banks et al., 2005). Input data is commonly use to represent environmental variables that change overtime whose statistical qualities can be seen in reality (Grimm et al., 2020). ABM requires to document where did the data originate and explain the biases, uncertainties and other limitations (Grimm et al., 2020). The type of data and how it is collected is dependant of the model of the experiment. This must be and is be explicitly stated in the Input Data of the ODD documentation.

5.6 Implementation: ABM solutions

Programming an agent based model from scratch allows for detailed control, however, this can take a lot of time as Graphical User Interfaces (GUI), visualisation, data importing and other non-specific content will use considerable time for the model to be implemented (Crooks & Heppenstall, 2012). The easier option is to use packages which provide conceptual frameworks, libraries with methods and functions, and templates for users to design custom models and thus these toolkits do not require substantial coding experience (Abdou et al., 2012; Crooks & Heppenstall, 2012). Softwares are also available to rapidly develop and construct basic or prototypes of ABMs (Crooks & Heppenstall, 2012). The trade-off is that learning to design and implement a model using a toolkit or software will limit what is learned to the context of said toolkit or software and its programming language (Crooks & Heppenstall, 2012). This may not yield the desired functionality (Crooks & Heppenstall, 2012). Nevertheless, the right toolkit and the right software can allow more time to be spent on research (Crooks & Heppenstall, 2012).

5.6.1 Approach to Representing Humans in ABM

Among the different forms to represent knowledge, the declaration of facts and procedural knowledge often as IF-THEN rules are the two basic forms that are usually accepted (Kennedy, 2012). There are different approaches to coding behaviours in ABM which are (Kennedy, 2012):

1. Mathematical custom coding directly in the simulation's programming language when required,
2. Implementing a conceptual framework in the system to be used,
3. Quality tools for research that model individual cognition to the millisecond.

5.6.2 Mathematical Behaviour

Mathematics can be used to simplify human behaviour into methods that model human behaviour (Kennedy, 2012). Alas using random number generators is not a suitable substitute to human behaviour as people are not random, instead, thresholds can be used to produce a specific behaviour when an environmental parameter passes said threshold (Kennedy, 2012). These simple behaviours while could be an approximate would still be explainable (Kennedy, 2012). Another approach would be to combine several parameters to model individuals' behaviour, alas, with this approach, humans are not validated as pure optimising agents by available data (Kennedy, 2012). The last approach known as Dynamic Modelling is to represent decision-making as "stocks and flows", which is similar to a hydraulic system with pipes, tanks, valves, and pumps (Kennedy, 2012). A more general approach may be used when modelling a more general behaviour (Kennedy, 2012).

5.6.3 Conceptual Behaviour

There are also conceptual frameworks that allow abstract concepts to model individual's decision-making instead of using mathematics and environmental parameters (Kennedy, 2012). Agents can also be made to learn (Crooks & Heppenstall, 2012).

Belief Desire Intention (BDI)

The Belief Desire Intention (BDI) develops decision trees using individual's beliefs as knowledge of the world they perceive, desires as their motivation or goals, and intentions as their different states of deliberation (Kennedy, 2012). This decision tree when completed transforms into a model of different possible social interactions where the best course of action is decided after it has been deliberated (Kennedy, 2012). The disadvantage of BDI is that it provides not much more than a conceptual framework to think about modelling individuals' cognition and behaviour (Kennedy, 2012).

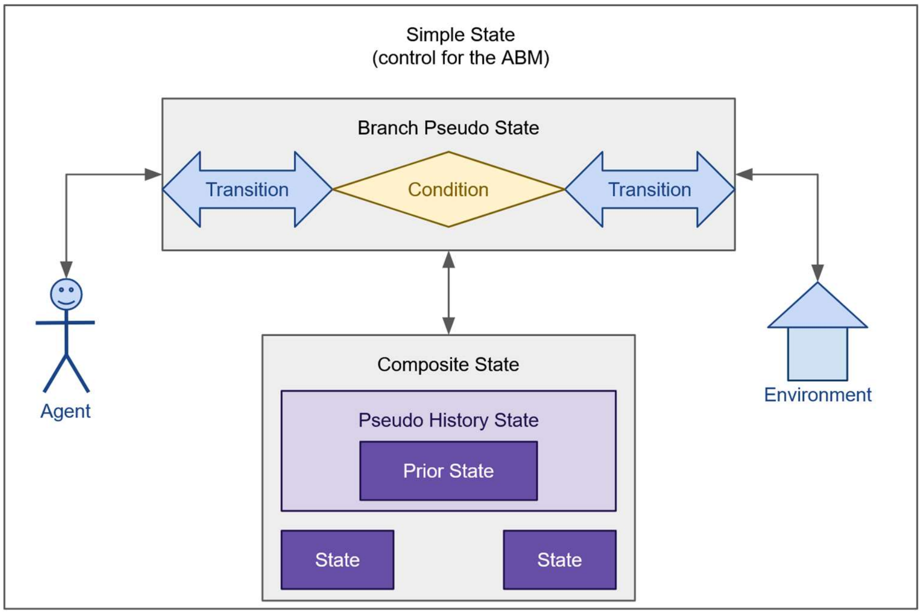
BDI in Education

Simpson-Singleton and Che (2019) research used ABM to assess Science Technology Engineering Mathematics (STEM) programs in education. The method used for their research is a form of BDI and can be readapted.

BDI ABM States

Simpson-Singleton and Che (2019) mostly use ABM within their study. There are also several states within ABM which include (Simpson-Singleton & Che, 2019):

- A simple state which controls the ABM,
- A pseudo history state that monitors the prior states inside a composite state,
- A composite state which has a group of states with mutual behaviours,
- A branch pseudo state which selects the conditions between transitions which is triggered by rules or events,
- And agents and environments are defined by behaviour rules, interaction rules and characteristics.



This figure represents the simplified ABM structure used by Simpson-Singleton and Che (2019)

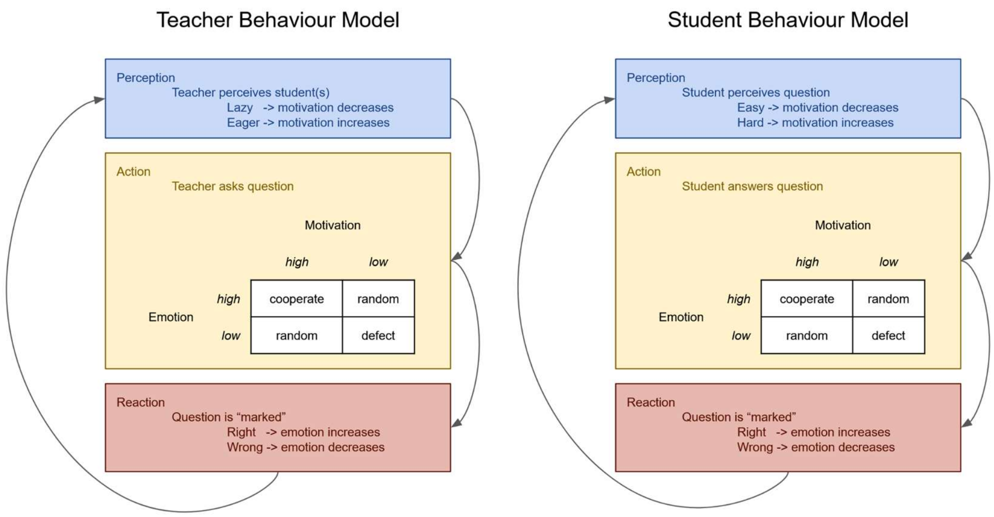
FIGURE 30. SIMPLIFIED ABM STRUCTURE

BDI Behaviour Model

The methods used to structure their study were (Simpson-Singleton & Che, 2019):

- Meta-Game of Learning, Game Theoretic Model and Iterative Prisoner's Dilemma were the basis used for the dialogic framework.
- An intelligent learning system model which can include an intelligent tutoring model or a traditional lecture-feedback model that were used to deliver lessons to the student.
- The quantity of teachers and students is user defined.
- The lesson progression rate, motivation and emotions are compared for each lesson model.

Simpson-Singleton and Che (2019) used different models for their study. These models have been repurposed for this. Simpson-Singleton and Che (2019) used teacher and student behaviour models.



These are the behaviour model used by Simpson-Singleton and Che (2019)

FIGURE 31. TEACHER AND STUDENT BEHAVIOUR MODEL

Here perception takes the role of belief where an agent's beliefs are determined by their perception. Action is where an agent makes his decision which holds their desires. Reaction represents an agent's intent to execute their action. This approach to compartmentalise an agent's perception, action, and reaction is simple.

Physical conditions, Emotional states, Cognitive capabilities and Social factors (PECS)

Behavioural framework such as Physical conditions, Emotional states, Cognitive capabilities and Social factors (PECS) allows for sophisticated handling of agent behaviour (Crooks & Heppenstall, 2012). PECS relies on mathematical representation of physiology, emotion, cognition and social status to represent the human mind including perceptions and behaviour (Kennedy, 2012). Cognition holds the mathematics to transform environmental model and self-model, memory of behaviour protocols, planning and reflection (Kennedy, 2012). This framework can be used for simple stimulus-response and complex behaviour that transforms drives, needs, and desires into motives which based on their intensity are state variables (Kennedy, 2012). Thus, behaviours can be indirectly determined by motives (Kennedy, 2012). This framework has the advantage to explain in a reasonable and plausible manner the causes for a behaviour (Kennedy, 2012). However, Kennedy (2012) point out that there are two challenges with PECS:

1. The internal parameters for the mathematical transformation of environmental parameters into internal state variables,
2. Combining, prioritising and integrating various motives into behaviours.

Fast and Frugal

"Fast and frugal" is the third framework which was developed by analysing human decisions (Kennedy, 2012). It performs very well when compared to human decisions making by using sequential questions as trees (Kennedy, 2012). While these trees do not justify the implementation of a particular behaviour as these do not aim at identifying all the variables, they are however computationally cheap and with a large number of agents should scale up well in ABM (Kennedy, 2012).

Conclusion

BDI, PECS, and "fast and frugal" are different approaches to modelling human behaviour while they allow a rigour between research quality of human cognition and pure mathematical representations (Kennedy, 2012).

5.6.4 Tools Used for Different Purpose

There is a third approach which is to use research tools whose purpose is to understand and research cognition that were originally developed for other purposes than ABM (Kennedy, 2012). These cognitive models can still be used to implement human behaviour in ABM (Kennedy, 2012). For example, Soaris AI system used to match human performance in problem solving tasks which could be considered as an implementation of BDI with a collection of rules written as text (Kennedy, 2012). ACT-R which uses declarative facts and rules is another tool which provides an architecture based on assumptions that has successfully demonstrated low level cognitive phenomena over short periods of time (Kennedy, 2012).

5.7 Conclusion

ABM is a suitable method using simulation research design to simulate knowledge transfer in organisations from individual characteristics such as ACAP and outliers.

Chapter 6: Experiment 1, ABM using ACAP

The following experiment focuses on using ACAP in ABM. It uses the dataset from Dolmark (2020). It answers this study's research questions 1. It has already been published as Dolmark et al. (2024).

6.1 Introduction

Knowledge is critical for organisational success (Garavelli et al., 2002; Goh, 2002; Hwang et al., 2008; Karlsen & Gottschalk, 2004; Othman et al., 2014). Once an organisation understands the importance of knowledge, they attempt to transfer knowledge where it can be used (Kuo & Lee, 2009; Vance & Eynon, 1998). Recipient's ACAP which is the dynamic capability to absorb knowledge (Cohen & Levinthal, 1990) is a barrier to knowledge transfer that has still no clear solution. Research into ACAP at the individual level has been neglected (Gao et al., 2017; Lowik et al., 2017; Minbaeva et al., 2012). ABM is a simulation (Abdou et al., 2012) which is classified as an individual model (Crooks & Heppenstall, 2012). This experiment attempts to use ABM to simulate knowledge transfer based on individual ACAP.

6.1.1 Research Aim

The aim of this research is to investigate organisational knowledge transfer from individuals' characteristics using computer simulation.

6.1.2 Research Objectives

The objectives of this research are to:

- Propose a method to simulate organisational knowledge transfer from individuals' characteristics.
- Propose a development process to build a computer simulation again for organisational knowledge transfer from individuals' characteristics.
- Run a computer simulation of said organisational knowledge transfer.

6.1.3 Research Purpose

The purpose of this research is to offer an approach to simulating knowledge transfer in organisations using ABM. While this experiment is set in a university course, this approach could lay the groundwork for future experiments.

6.1.4 Research Significance

This research main significance is students as this research models uses their ACAP to model the collective ACAP they are in and how others student affects their learning.

This research would also be of benefit to:

- The social media industry which could use this approach with their data to simulate and predict how their users interact and behave on their systems.
- Management which could use this approach to model knowledge transfer in their organisation. They could also use this to predict members' performances including managers, decision makers and anyone who has substantial power internally.
- The education industry which would use this model to observe how their students will behave.
- The IT and AI discipline which would benefit from another use for ABM.
- Students, employees and other knowledge recipients would also benefit from this as this could provide them with some sort of understanding of where and how the knowledge will come to them and who they may go to.
- Academia will of course benefit from further knowledge contribution.

6.2 Literature Review

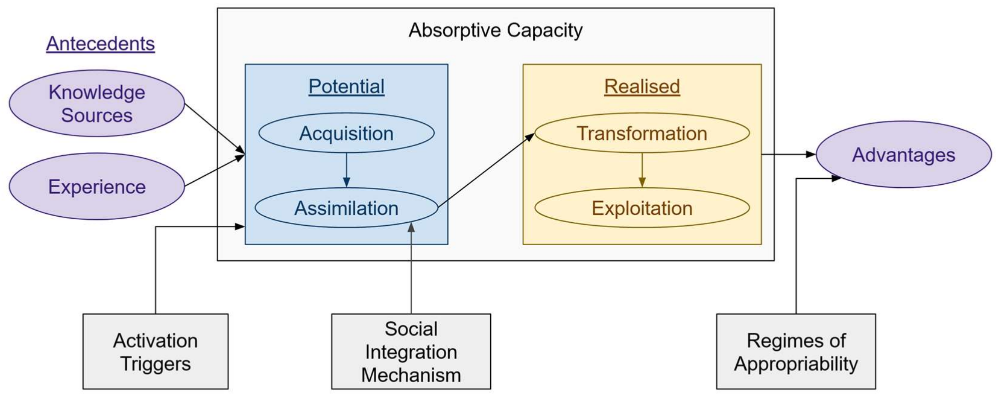
While knowledge is intangible (Lopez-Cruz & Garnica, 2018), It is made of various abstract elements, it is dynamic in its structure and relies on intuition (Davenport & Prusak, 1998, p. 5). Knowledge has been defined differently across history by many different authors from Plato (1999) famous statement that knowledge is justified true belief (Vance & Eynon, 1998) to Davenport and Prusak (1998, pp. 2-6) whose recent definition that when data has meaning, it is information, and when information has been experienced, it is knowledge (Garavelli et al., 2002; Karlsen & Gottschalk, 2004).

Knowledge is critical for organisations to succeed (Garavelli et al., 2002; Goh, 2002; Hwang et al., 2008; Karlsen & Gottschalk, 2004; Othman et al., 2014). When an organisation is aware of the importance of knowledge, a lot of resources are spent to manage it (Iyengar et al., 2015) and attempt to transfer knowledge where it can be used (Kuo & Lee, 2009; Vance & Eynon, 1998). And yet, regardless of how much organisations fully dedicate to knowledge management, barriers to knowledge transfer can still exist (Szulanski, 1996). Szulanski (1996) found that among the common barriers to knowledge transfer the most common ones were causal ambiguity, an arduous rapport between knowledge holder and recipient, and recipient's ACAP. Causal ambiguity is when the cause of an effect is uncertain or unknown (Szulanski, 1996). An arduous rapport between knowledge holder and recipient is believed to originate from a punitive and distrustful organisational culture (Goh, 2002). Also withholding critical information is a means for managers to assert power (Goh, 2002). Unlike a traditional vertical structure where one manager has many employees, horizontal structures allow communication to flow across business functions (Goh, 2002). They promote trust and disseminate aspirations (Goh, 2002; Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013). They are an effective solution to causal ambiguity, and rapport between knowledge holder and recipient (Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013) but leaving the recipient's ACAP unaffected and unresolved.

6.2.1 Absorptive CAPacity (ACAP)

ACAP is the dynamic capability to absorb knowledge (Cohen & Levinthal, 1990). For further information about ACAP, please refer to chapter 2 and 3. There have been many different versions of ACAP from Cohen and Levinthal (1990) who first introduced it, to Todorova and Durisin (2007) with their more recent revision. While all these different versions differ with nuances that are important, these different versions portray the same narrative which starts with "not knowing" and ends with "knowing". Zahra and George (2002) version is considered a staple version as it had introduced elements missing from Cohen and Levinthal (1990) while remaining simple enough to make it clear to understand. Their version recognises four different capabilities in its absorption process (see figure 32):

1. **Acquisition** is the first capability where the object of knowledge is acquired (Zahra & George, 2002).
2. In the **Assimilation** capability, the knowledge is extracted from the object (Zahra & George, 2002). This is where knowledge is comprehended or understood.
3. **Transformation** is where processes are re-configured so that the newly acquired knowledge can be exploited (Zahra & George, 2002). The amount of time and effort required to unlearn and relearn the new processes and knowledge with the old one is proportional to how much prior knowledge is ingrained (Szulanski, 2000). This is where knowledge is reflected or thought.
4. **Exploitation** is where knowledge is used and its value is returned (Zahra & George, 2002). Exploiting knowledge is often viewed as a successful demonstration that knowledge has been absorbed (Jacobs & Buys, 2010).



This diagram illustrates Zahra and George (2002) Absorptive Capacity.

FIGURE 32. ABSORPTIVE CAPACITY BY ZAHRA AND GEORGE (2002)

6.2.2 Research Gap

Most ACAP research has been in innovation, performance and knowledge transfer from the perspective of organisations (Jansen et al., 2005; Lowik et al., 2017; Yao & Chang, 2017). Cohen and Levinthal (1990, p. 131) remarked that "an organisation's absorptive capacity will depend on the absorptive capacities of its individual members" and that "a firm's absorptive capacity is not simply the sum of the absorptive capacities of its employees". As organisations are made of individuals (Cohen & Levinthal, 1990, p. 131), an individuals' behaviour is the root to organisation's knowledge transfer (Minbaeva et al., 2012). While research into ACAP as a barrier at the individual level has been neglected (Gao et al., 2017; Lowik et al., 2017; Minbaeva et al., 2012), it has been at an individual level (Lowik et al., 2017).

6.2.3 Research Questions

RQ1 How does interaction between individuals affect organisational knowledge transfer?

6.2.4 Scope

The scope of this experiment is to model agents ACAP in an ABM simulation and observe the effect of knowledge spillover whether absent, absolute, or in-between on said agents. Students being actively absorbing knowledge which is ACAP are the ideal population to collect data from. Data for students' ACAP was collected in Dolmark (2020).

6.2.5 Hypothesis Development

Here follows several hypotheses developed for this experiment.

RQ1: How does interaction between individuals affect organisational knowledge transfer?

As horizontal organisational structures allow communication to flow between departments, they resolve the barriers of causal ambiguity, and rapport between knowledge holder and recipient (Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013). Higher network diversity also enhances individuals' innovation capability (Lowik et al., 2017). This suggests that interactions between individuals may improve knowledge transfer.

Hypothesis 1a: Interactions between individuals enhances organisational knowledge transfer.

However, there are times when interactions can be a barrier to knowledge transfer, for example, an arduous relation between the knowledge holder and recipient (Szulanski, 1996).

Hypothesis 1b: Interactions between individuals diminished organisational knowledge transfer.

6.3 Methodology: Agent Based Modelling

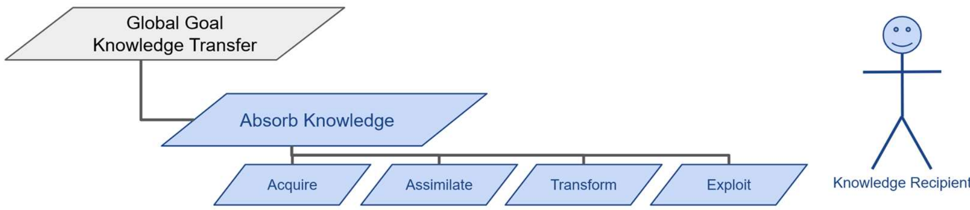
ABM are catalogued as individual based models (Crooks & Heppenstall, 2012). ABM are simulations where agents being representations of how social actors react in a computer environment representing a real-world environment (Abdou et al., 2012). While the behaviour of individuals can be inconsistent, noisy or unexpected, as individuals have different skills and knowledge, their decisions are not a random selection between different options (Kennedy, 2012). Individuals decide what actions to take based on what they remember, their current state, and the information they receive (Kennedy, 2012). While it is often believed that individuals behave rationally (Jacoby, 2002; Kennedy, 2012), rationality is judged by external norms (Jacoby, 2002). ABM gives researchers the ability to create, analyse and experiment with models made of agents interacting in an environment (Abdou et al., 2012). Simulations where individuals make decisions allow for a bottom-up approach to human simulation systems (Crooks & Heppenstall, 2012). ABM is a simulation where agents' decisions are not random but based on a rationale. An agent’s behaviour is determined by their rationale and to model this, it requires knowledge to be represented, absorbed, remembered, and applied (Kennedy, 2012). This aligns well with ACAP. In theory, ABM can be used to simulate agents' behaviour based on their ACAP. Dolmark (2020) provides the data and other material to run this experiment.

6.3.1 Analysis: Role Oriented Analysis and Design for Multi-Agent Programming (ROADMAP) method

The ROADMAP method separates analysis with goal model, role model and social model, from design with agent model, interaction model and the inclusion of an ABM architecture at this stage (Kuan et al., 2005). Using this method allows for scalability and ease of use (Kuan et al., 2005).

Goal Model

The goal model is the starting point where experts settle on what the system is meant to achieve and contains goals, quality goals (non-functional requirements) and roles (Kuan et al., 2005).



This diagram illustrates the goal model

FIGURE 33. GOAL MODEL

TABLE 13. GOAL MODEL NOTATIONS SUMMARY (KUAN ET AL., 2005)

Notation	Representation/Meaning
	Goal
	Quality Goal
	Role
	To show relationship between Goal/ Quality Goal with its related Sub-Goals/Sub-Quality Goal
	To show connection between elements

The data from the original study (Dolmark, 2020) only collected data from students otherwise considered as the knowledge recipient. Based on this, the general goal of knowledge transfer is confined to the goal of absorbing knowledge for knowledge recipients which can be decomposed into sub-goals of acquire, assimilate, transform, and exploit.

Role Model

A role is a position required to achieve a system requirement and can be decomposed into one-to-many agents (Kuan et al., 2005). The role model has a name, a description, a list of responsibilities, and a list of constraints or conditions that the role will have to take into account when executing its responsibilities (Kuan et al., 2005).

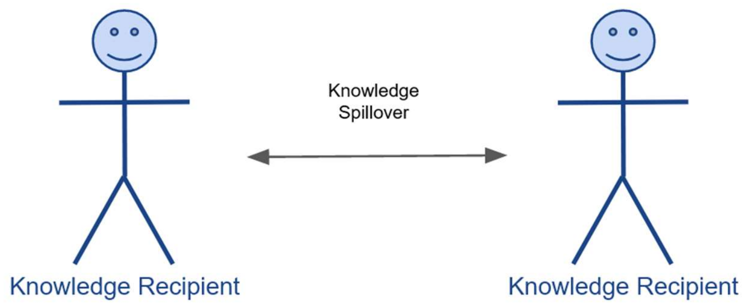
TABLE 14. ROLE MODEL

Role ID	KR1
Name	Knowledge Recipient
Description	Absorb knowledge received. Reconcile new knowledge with their own experience.
Responsibilities	
Constraints	Motivation: A knowledge Recipient must be motivated to absorb knowledge. Time: A Knowledge Recipient needs time and effort to reconcile new knowledge from a knowledge source with their own personal experience. The more the knowledge and experience contradict, the more time and effort is required to reconcile knowledge with experience (Szulanski, 2000)

There is only one role model for this experiment which is knowledge recipient. Knowledge recipient's constraints would be their motivation to learn, and the amount of time they have.

Social (or Organisational) Model

The social or organisational model describes the relation between different roles and the rules or policies of their interactions (Garro & Russo, 2010; Kuan et al., 2005).



This diagram illustrates a social or organisational model

FIGURE 34. SOCIAL MODEL

Students would be considered peers and as knowledge recipients they would share knowledge. This would be referred to as knowledge spillover.

Environmental Model

An environmental model depicts environmental entities in a particular domain and is used to describe holistically the environment of the system (Juan et al., 2002). Environmental entities raise phenomena (Zhi, 2018). Environmental entities were not considered in Dolmark (2020); hence, they will not be considered in this experiment.

Agent Model

An agent model details the activities that an agent's behaviour is meant to achieve to fulfil its goal (Garro & Russo, 2010). These are not to be confused with course activities which are activities related to a university course.

TABLE 15. AGENT MODEL

Agent ID	KR	Agent Name	Knowledge Recipient

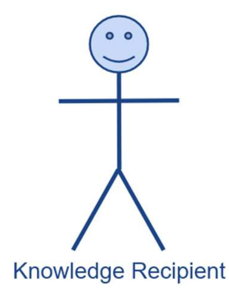
Activity Name	Acquire
Roles Played	Knowledge Recipient
Functionality	Acquire knowledge
Precondition	Start Or Received knowledge spillover
Postcondition	Knowledge will be assimilated

Activity Name	Assimilate
Roles Played	Knowledge Recipient
Functionality	Assimilate knowledge
Precondition	Knowledge must be acquired
Postcondition	Knowledge will be transformed

Activity Name	Transform
Roles Played	Knowledge Recipient
Functionality	Transform knowledge
Precondition	Knowledge must be assimilated
Postcondition	Knowledge will be exploited

Activity Name	Exploit
Roles Played	Knowledge Recipient
Functionality	Exploit knowledge
Precondition	Knowledge must be transformed
Postcondition	End Or Spillover to another knowledge recipient

Environmental Considerations



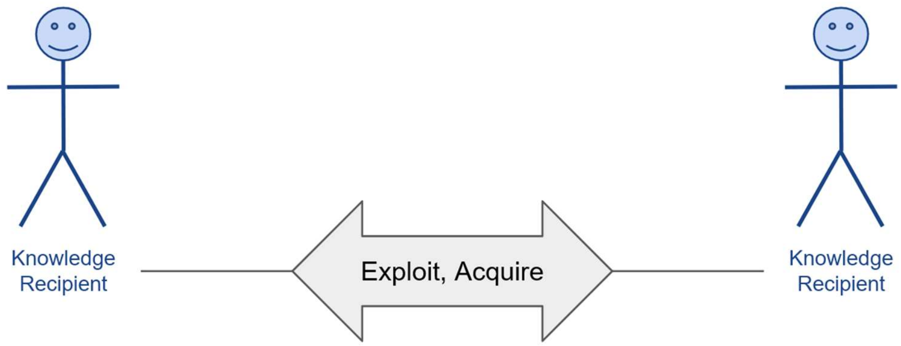
This diagram illustrates an agent model

FIGURE 35. AGENT MODEL

Each activity represents a capability of ACAP from Zahra and George (2002) who recognised acquisition, assimilation, transformation, and exploitation.

Interaction Model

The interaction model details the activities in which the agents interact with (Garro & Russo, 2010).



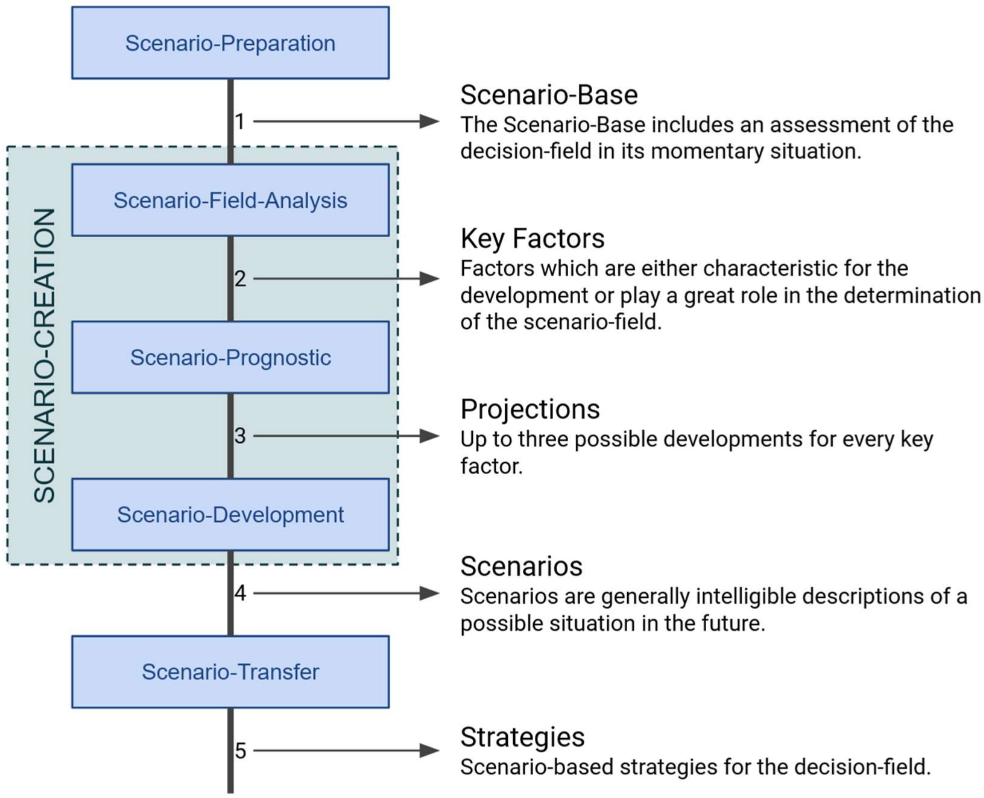
This diagram illustrates an interaction model.

FIGURE 36. INTERACTION MODEL

The interaction between two knowledge recipients would be knowledge spillover. While this interaction would consume the motivation of each knowledge recipient, this motivation is distinct between agents.

6.3.2 Scenario Analysis

Scenarios present many pictures of different possible futures and aid with limited and strategic thinking (Amer et al., 2013; Guenther et al., 2017). While scenario planning is not a prediction, it is different sights into futures for which business leaders can choose (Gausemeier et al., 1998).



This diagram presents the different phases to managing a scenario by (Gausemeier et al., 1998).

FIGURE 37. PHASES OF SCENARIO MANAGEMENT (GAUSEMEIER ET AL., 1998)

Gausemeier et al. (1998) propose five different phases to develop a scenario:

1. Scenario preparation is where the object of a scenario is decided. The present context should determine the decision field before any visions as scenarios are developed (Gausemeier et al., 1998). This experiment presents a simulation model for knowledge transfer with ACAP using ABM. The object of this study is ACAP at the individual level and how it affects larger collectives.

2. Scenario-fields analysis is where key factors of influence are determined. Key factors can be determined with an influence matrix or a system grid (Gausemeier et al., 1998). As the data comes from Dolmark (2020), the key factors are acquisition, assimilation, transformation and exploitation. All capabilities forming ACAP are to some degree interdependent on each other. Yet each ACAP capability will depend on the one that precedes it. Exploitation is dependent on transformation which is dependent on assimilation which is dependent on acquisition. And yet Limaj and Bernroider (2019) states that

potential ACAP which is made of acquisition and assimilation has a positive effect on realised ACAP which is made of transformation and exploitation. At the individual level, assimilation can be thought of as comprehension (Zahra & George, 2002) and transformation as reflection (Lowik et al., 2017). As comprehension and reflection are intertwined, assimilation and transformation are also viewed to be strongly tied together, and therefore have a strong impact on each other.

TABLE 16. SCENARIO FIELD ANALYSIS

Influence Matrix Question: "How strong is the impact of factor x row on factor y column?" Scale: 0 = no impact 1 = weak and delayed impact 2 = medium impact 3 = strong and direct impact	Acquisition	Assimilation	Transformation	Exploitation	Active Sum (sum of rows): How strong is the impact of a factor on all other factors?
Acquisition		3	3	3	9
Assimilation	1		3	3	7
Transformation	1	3		3	7
Exploitation	1	1	1		3
Passive Sum (sum of rows): How strong is a factor impacted by all other factors?	3	7	7	9	

3. Scenario prognostic is where the projections are developed (Gausemeier et al., 1998).

TABLE 17. PROJECTION CATALOGUE

Projection Catalogue				
One will find up to 3 possible developments per factor. Those projections are worked out and described "in prose".				
Acquisition	Alternative Projections	A: Knowledge recipient is not acquiring knowledge	B: Recipient acquires knowledge	C: Recipient cannot acquire knowledge
Assimilation	Alternative Projections	A: Recipient is not assimilating knowledge	B: Recipient is assimilating knowledge	
Transformation	Alternative Projections	A: Recipient is not transforming knowledge	B: Recipient is transforming knowledge	
Exploitation	Alternative Projections	A: Recipient is not exploiting knowledge	B: Recipient is exploiting knowledge	C: Recipient cannot apply knowledge

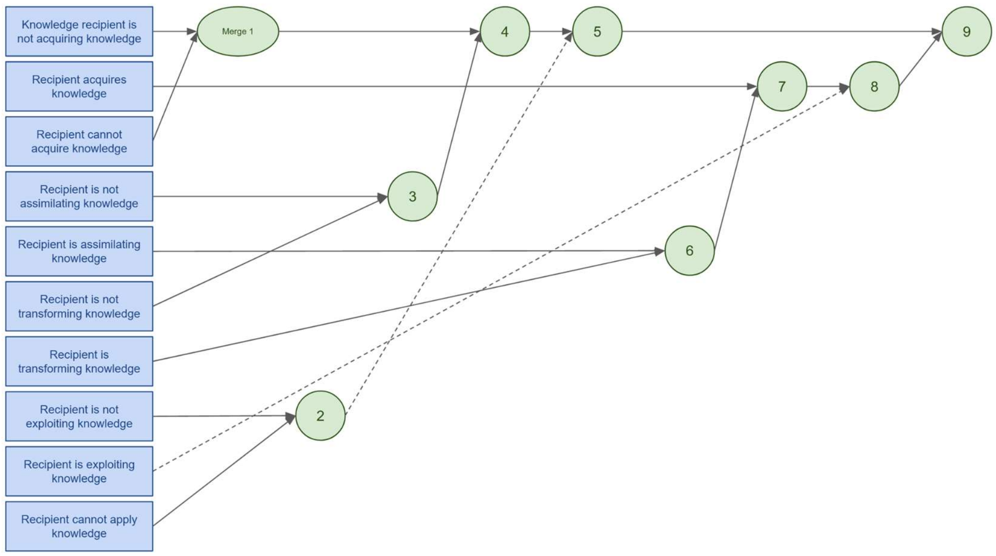
4. In the scenario development, the first step is to perform a consistency analysis (Gausemeier et al., 1998). Not acquiring knowledge would have a direct causal effect to not exploiting knowledge as an individual cannot apply what they do not know. Therefore, there is a strong consistency to not being able to exploit knowledge from not acquiring knowledge. An individual may have some prior experience that they may apply but this would be the application of different knowledge. And yet, the reverse may not be true, acquiring knowledge may not have a direct causal effect to applying said knowledge. There is no consistency or inconsistency to not exploiting knowledge from acquiring knowledge. It is neutral. If a projection's ACAP capability is adjacent with another ACAP capability, then the consistency scale would skew away from neutrality. For example, as assimilation follows acquisition then the projection that a knowledge recipient assimilates knowledge is consistent with a knowledge recipient acquiring knowledge rather than neutral. These different rationales can be applied to all projections.

TABLE 18. CONSISTENCY MATRIX

Consistency Matrix Question: “How consistent is projection x row with projection y column?” Scale (consistency): 1 = total inconsistency 2 = partial inconsistency 3 = neutrality or independency 4 = consistency 5 = strong consistency			Knowledge recipient is not acquiring knowledge	Recipient acquires knowledge	Recipient cannot acquire knowledge	Recipient is not assimilating knowledge	Recipient is assimilating knowledge	Recipient is not transforming knowledge	Recipient is transforming knowledge	Recipient is not exploiting knowledge	Recipient is exploiting knowledge	Recipient cannot apply knowledge
			aA	aB	aC	bA	bB	cA	cB	dA	dB	dC
Acquisition	aA	Knowledge recipient is not acquiring knowledge										
	aB	Recipient acquires knowledge										
	aC	Recipient cannot acquire knowledge										
Assimilation	bA	Recipient is not assimilating knowledge	5	3	5							

	bB	Recipient is assimilating knowledge	1	4	1							
Transformation	cA	Recipient is not transforming knowledge	5	3	5	5	4					
	cB	Recipient is transforming knowledge	1	3	1	1	5					
Exploitation	dA	Recipient is not exploiting knowledge	5	3	5	5	3	5	3			
	dB	Recipient is exploiting knowledge	1	3	1	1	3	1	4			
	dC	Recipient cannot apply knowledge	5	3	5	5	3	5	3			

The next step is to perform a cluster analysis (Gausemeier et al., 1998).



This diagram illustrates cluster analysis

FIGURE 38. CLUSTER ANALYSIS

The "elbow point" which is the sudden increase in loss of information allows one to identify the ideal grouping of scenarios (Gausemeier et al., 1998). The biggest loss of information occurs at merge 8 with the merge of "negative" ACAP and "positive" ACAP. The last step is analysing each cluster of scenarios and assigning a prosaic description to each one (Gausemeier et al., 1998). Merge 8 contains two different clusters of projections or scenarios: a "positive" ACAP which will be described as "Recipient absorbed knowledge" and a "negative" ACAP which will be "Recipient does not absorb knowledge".

5. Scenario transfer begins with the consequence analysis with opportunities and threats (Gausemeier et al., 1998). The decision field components for this experiment would simply be “knowledge transfer”.

TABLE 19. CONSEQUENCE MATRIX

Decision field	Scenario field	Recipient absorbed knowledge	Recipient does not absorb knowledge
Decision field component			
Knowledge transfer		- The knowledge recipient is able to exploit knowledge. - The knowledge recipient is able to exploit knowledge and if the context allows for knowledge recipients to interact then there may be spillover.	- The knowledge recipient is unable to exploit knowledge.

- Systematic registration of **consequences** of scenarios on the decision-field
- Direct derivation of **opportunities** and **threats** for the decision-field
- Registration of consequences including actual **strengths**, **weaknesses** and the **systemic behaviour** of similar decision-field components

An “action portfolio” can then be set to trigger when a corresponding scenario matches a “real” future (Guenther et al., 2017).

6.3.3 Design: Overview, Design concept, and Detail (ODD)

By allowing others to replicate a model by supplying the parameters, data, source code, and descriptions, it can increase its underlying assumptions and its confidence (Crooks & Heppenstall, 2012). The "Overview" provides an overview, the "Design Concepts" details the designs used, and the "Details" explains all the extra details for the model (Grimm et al., 2020).

1. Purpose

"Overviews" first section, "Purpose and patterns", briefly describes the model's purpose and the patterns that are used to evaluate the model (Grimm et al., 2020). The purpose of this study is to model organisational knowledge transfer based on individuals' ACAP using ABM. This experiment has a very simple model and uses data from already existing data sources. Data source used will be the same data source used in Dolmark (2020).

2. Entities, Variables, and Parameters

The second section, "Entities, state variables and scales", lists the different entities in the model along with their state variables and definition, as well as the model's spatial and temporal resolution (Grimm et al., 2020). The data source from Dolmark (2020) was collected using items from Lowik et al. (2017), Jansen et al. (2005), Vlačić et al. (2019) for ACAP and Koopmans et al. (2013), and Pradhan and Jena (2017) for the individual work performance. This individual work performance focuses on behaviour or actions under the control of an employee rather than the outcome (Koopmans et al., 2013). Said data source is suitable for this experiment to model an individual's ACAP in an ABM to simulate organisational knowledge transfer.

TABLE 20. LIST OF ENTITIES, VARIABLES AND PARAMETERS FROM PREVIOUS LITERATURE

Name	Description	Parameter, Variable, or Entity
Individuals		
Knowledge Recipient	Recipients of external knowledge (Szulanski, 1996).	Agent
Absorptive Capacity	Cohen and Levinthal (1990) first introduced the concept of ACAP as an organisation's capability to absorb knowledge. While ACAP is popular for organisations, research has used it at an individual level (Lowik et al., 2017)	Construct
Acquisition	Acquisition is the first capability where the object of knowledge is acquired (Zahra & George, 2002). Scholars have often included value recognition with Acquisition (Todorova & Durisin, 2007). Some support that this is an independent capability from acquisition (Cuervo-Cazurra & Rui, 2017; Todorova & Durisin, 2007), others argue the difference between recognising the need from value (Cuervo-Cazurra & Rui, 2017).	Parameter
Assimilation	Assimilation is defined as the capability to extract knowledge from an object (Zahra & George, 2002).	Parameter

Transformation	Transformation is the capability to reconfigure its knowledge process to connect it with prior knowledge (Zahra & George, 2002). It has been argued that Assimilation and Transformation are separate capabilities (Jansen et al., 2005; Todorova & Durisin, 2007).	Parameter
Exploitation	In exploitation, knowledge is used and its value is returned (Zahra & George, 2002).	Parameter
Spillover	The recipient's i comprehension acts as a restriction from involuntary spillover from other recipients and it sets a range around the recipient i from which external knowledge can be absorbed (Savin & Egbetokun, 2016). A recipient i can also gain knowledge from voluntary spillover (δc) from a source j (Savin & Egbetokun, 2016).	Parameter
Spatial unit		
Time	The more ingrained the experience is, the more time will be needed to unlearn and relearn new knowledge (Szulanski, 2000).	Unit

3. Process Overview and Scheduling

Section 3, "Process overview and scheduling", gives an overview of the model's processes with their order, their time, and what state variables are updated (Grimm et al., 2020). ABM can emulate different timescales using different clocks for different processes in a single simulation (Crooks & Heppenstall, 2012; Torrens, 2003). An agent's behaviour can be synchronous so that changes occur at the same set time or asynchronous where actions are triggered either by a clock or by another agent's action (Crooks & Heppenstall, 2012).

Course Structure at University of Technology Sydney (UTS)

As the data was collected at University of Technology Sydney (UTS) (see Dolmark (2020)), scheduling should be representative of a stereotypical course at UTS. A stereotypical course at UTS Faculty of Engineering and Information Technology is twelve weeks long where each week is a lesson. A lesson is made of a lecture which is 90 minutes long and a tutorial which is also 90 minutes long. A lesson is 180 minutes in total. UTS recommends that students spend 9 hours a week completing extra homework however this is up to the student. While for each lesson the amount of new knowledge for a student to absorb is referred to by Savin and Egbetokun (2016) as cognitive distance (d_{ij}), for this experiment, as the data collected did not measure cognitive distance per student, an assumption is made that for each lesson the cognitive distance for all students is set to its maximum of 1. As each lesson is assumed independent of each other, this means that the scope of this experiment can simply be of a lesson and not of a course. In conclusion, the schedule for this experiment would be for a lesson which is 180 minutes.

4. Design Concepts

Design concepts” only has one section, Section 4, “Design concepts”, which includes 11 concepts important for designing the ABM model (Grimm et al., 2020).

Basic Principles

This section introduces the ideas, theories, and modelling approaches of the system and agents, and how they relate to each other (Grimm et al., 2020). While ACAP has been popular at the organisational level, it has been used at the individual level (Lowik et al., 2017). This study setting is a university course as the data collected was from the same setting.

Emergence

Scenarios establish how the simulation is set up (Garro & Russo, 2010). Scenarios are meant to represent an agent's activities and their sequence. For example, a student at a university has during a semester different courses with different activities such as lectures, tutorials, quizzes, homework and a final exam all happening at different rhythms and time. As mentioned earlier in “Process Overview and Scheduling”, the focus of this experiment is a lesson. Running a simulation using student ACAP would determine what variables affect collective knowledge transfer.

Adaptation

Adaptation defines which stimuli affects what decision for agents' behaviours (Grimm et al., 2020). Savin and Egbetokun (2016) offers a mathematical approach to ACAP. The context of this study focuses on the knowledge transfer to a knowledge recipient (i) (which Savin and Egbetokun (2016) calls a firm) from a knowledge source (j) (which Savin and Egbetokun (2016) calls potential partner). Using this mathematical formula with the data provided from Dolmark (2020) and making some assumptions, other values can be reverse engineered.

Cognitive Distance

Savin and Egbetokun (2016) defines the variable of cognitive distance (d_{ij}) between the recipient *i* from a source *j*. This distance is attributed to the recipient in the interval [0, 1]. For this experiment, students (which are in this experiment the recipients) are assumed to not know what teachers (the source) know. As said before in section 3, the cognitive distance is assumed to be of its maximum possible value of 1 for each lesson.

Absorptive CAPacity (ACAP)

ACAP can be represented as the function ($an_{i,j}$) of knowledge absorbed by the recipient *i* from a source *j* (Savin & Egbetokun, 2016). The data set from Dolmark (2020) contains measurements for this capability. The median for each record is calculated to provide a value for ACAP.

Rate & Period

A lesson is made of 1 lecture of 90 minutes and one tutorial of 90 minutes. A lesson is a period (t) of 3 hours or 180 minutes for each lesson. As a recipient *i* would absorb the cognitive distance assumed 1 over a period of time. The rate (*r*) can be calculated as over the cognitive distance (d_{ij} = 1) a student uses their ACAP (median of each capability $an_{i,j}$) on a period (*t*):

$$r = \frac{d_{ij}}{an_{i,j} * t}$$

EQUATION 2. ABSORPTIVE CAPACITY RATE

This formula provides the rate of knowledge absorption for each knowledge recipient *i* based on their survey response.

Spillover

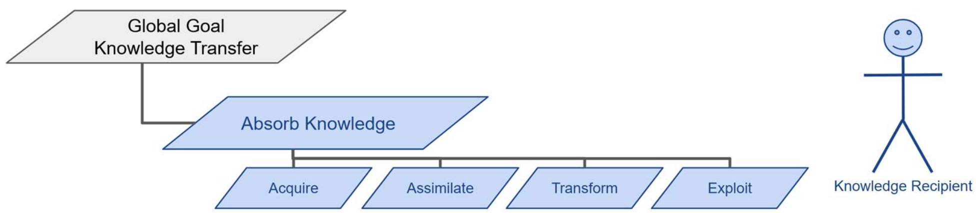
The knowledge spillover variable was not measured in Dolmark (2020). While it may be possible to reverse engineer a spillover rate, it would be more valuable to run multiple simulations and observe how knowledge spillover might affect collective knowledge transfer. This would provide insight if and when collaboration enhances or diminishes collective knowledge transfer.

Objectives

If agents' behaviours are modelled to increase their success at achieving a goal, then the measurements, their representations, and their calculations need to be explained (Grimm et al., 2020). The objective section is where the objective measurements of agents' actions working towards a goal is defined (Grimm et al., 2020).

Goals

As the goal model has already been defined, the objectives can easily be derived from it.



This diagram is a goal model for a knowledge recipient to absorb knowledge in transfer.

FIGURE 39. GOAL MODEL FOR KNOWLEDGE RECIPIENT TO ABSORB KNOWLEDGE IN KNOWLEDGE TRANSFER

In this experiment, the objective of a knowledge recipient is to acquire, assimilate, transform and exploit knowledge.

Role Model

Role models have been kept generic to be reusable. The generic roles in knowledge transfer includes Knowledge Recipient. The sole constraints of the knowledge recipient here are determined by ACAP which is to acquire, assimilate, transform and exploit.

TABLE 21. ROLE MODEL FOR A KNOWLEDGE RECIPIENT IN TRANSFER OF KNOWLEDGE USING ACAP

Role ID	KR1
Name	Knowledge Recipient
Description	Absorb knowledge from a Knowledge Source.
Responsibilities	A knowledge recipient's sole responsibility is to absorb new knowledge.
Constraints	Acquire Assimilate Transform Exploit

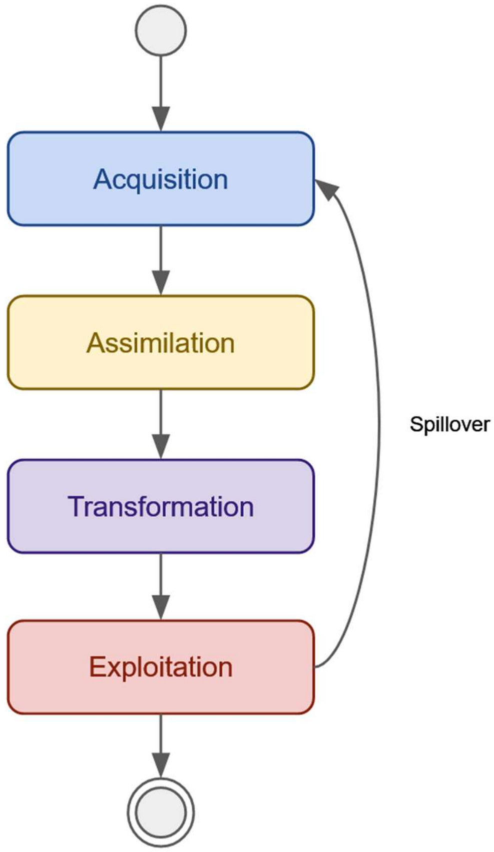
This table is the role for knowledge recipients in this experiment.

Measurements

This paper will use the data set from Dolmark (2020) as it has already been used to quantify ACAP constructs in said previous study.

Representations

During the process of ACAP, a knowledge recipient will be in a different state. These states have already been defined as the goals of ACAP which are acquired, assimilated, transformed, and exploited.



This diagram illustrates the different states of a knowledge recipient's Absorptive Capacity.

FIGURE 40. STATE TRANSITION DIAGRAM FOR A KNOWLEDGE RECIPIENT

Calculations

The data set from the Dolmark (2020) study can be used to calculate transition durations between each different state of ACAP for each agent.

Learning, Prediction and Sensing

As this is not applicable to this study, learning, prediction, and sensing will not be expanded upon.

Interaction

Activities

An agent model details the activities an agent's behaviour meant to achieve its goal (Garro & Russo, 2010). For this experiment, the knowledge recipient is a student and their activities are the capability of ACAP. These activities have been described before in the agent model, nevertheless, they also have interactions.

TABLE 22. AGENT MODEL

Agent ID	KR	Agent Name	Knowledge Recipient

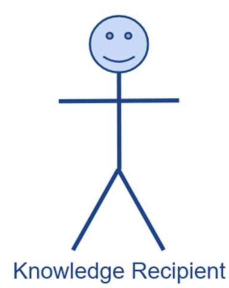
Activity Name	Acquire
Roles Played	Knowledge Recipient
Functionality	Acquire knowledge
Precondition	Start Or Received knowledge spillover
Postcondition	Knowledge will be assimilated

Activity Name	Assimilate
Roles Played	Knowledge Recipient
Functionality	Assimilate knowledge
Precondition	Knowledge must be acquired
Postcondition	Knowledge will be transformed

Activity Name	Transform
Roles Played	Knowledge Recipient
Functionality	Transform knowledge
Precondition	Knowledge must be assimilated
Postcondition	Knowledge will be exploited

Activity Name	Exploit
Roles Played	Knowledge Recipient
Functionality	Exploit knowledge
Precondition	Knowledge must be transformed
Postcondition	End Or Spillover to another knowledge recipient

Environmental Considerations

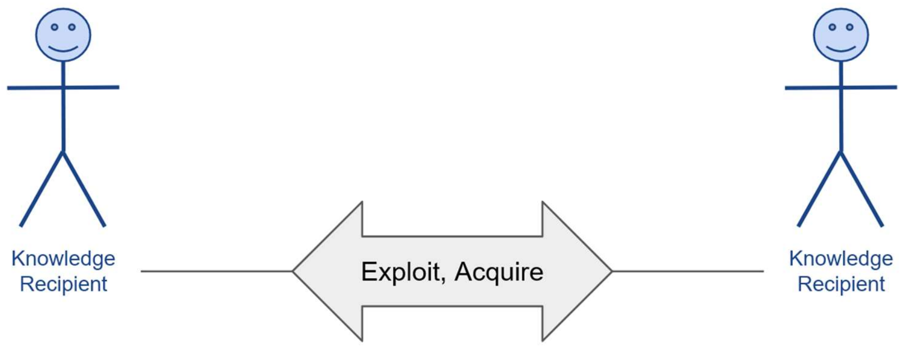


This diagram illustrates the different activities a knowledge recipient or student can perform.

FIGURE 41. ACTIVITY MODEL FOR KNOWLEDGE RECIPIENT AS A STUDENT IN A UNIVERSITY COURSE

Interactions

The interaction model details the activities in which the agents interact with (Garro & Russo, 2010).



This diagram illustrates the different interactions as activities a knowledge recipient or source can perform with another or alone.

FIGURE 42. INTERACTION MODEL FOR KNOWLEDGE RECIPIENT AS A STUDENT IN A UNIVERSITY COURSE

In this experiment, a knowledge recipient or student will interact with another student to transmit knowledge. This has been described before as a knowledge spillover. A knowledge spillover would require one agent to exploit knowledge to share it and another agent to listen. This interaction would only take place during course activities that allow students to interact with each other.

Stochasticity

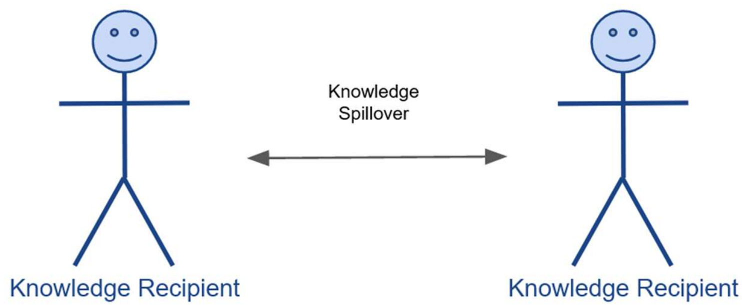
In the stochasticity section, the use of random numbers in the model is described (Grimm et al., 2020). At initialisation, a pseudorandom number generator can be used to set some of the values of agents (Grimm et al., 2020). Stochasticity or randomness used correctly would mimic the randomness of the real world such as involuntary spillovers δ_n. However, in this experiment, stochasticity has not been used.

Collectives

This section describes groups or collectives that are affected by or affect agents (Grimm et al., 2020). For this experiment, the collective is not used.

Social Model

The social or organisational model describes the relationship between different agents (Kuan et al., 2005). This model can help articulate relationships between agents:



This organisational diagram illustrates the different relationships between knowledge recipients.

FIGURE 43. SOCIAL MODEL FOR KNOWLEDGE RECIPIENT AS A STUDENT IN A UNIVERSITY COURSE

Knowledge recipients are peers to one another. The only interaction they can have was knowledge spillovers.

Observation

Running the simulation multiple times with different spillover rates would allow the observation of different collective knowledge transfer. This observation could be compared to determine the effect of knowledge spillover. This would require at the very least 2 simulations with one spillover rate of 0 to represent students not interacting with one another and another which can be of value of 1. This would provide results without having to actually depend on a real-life experiment.

5. Initialization

Setting up the simulation

In initialization, the creation of different entities with their variable when the simulation begins (Grimm et al., 2020). For this experiment, the simulation was designed and executed using AnyLogic 8 Personal Learning Edition 8.8.1 (Build: 8.8.1.202210270952 x64). The simulation was set to minutes.

Main Model

In the "Main - agent type" window, within its "Properties" tab, under the "Space and network" section, the "Layout type:" dropdown box was set to "Random". This will display agents at one random location in the simulation.

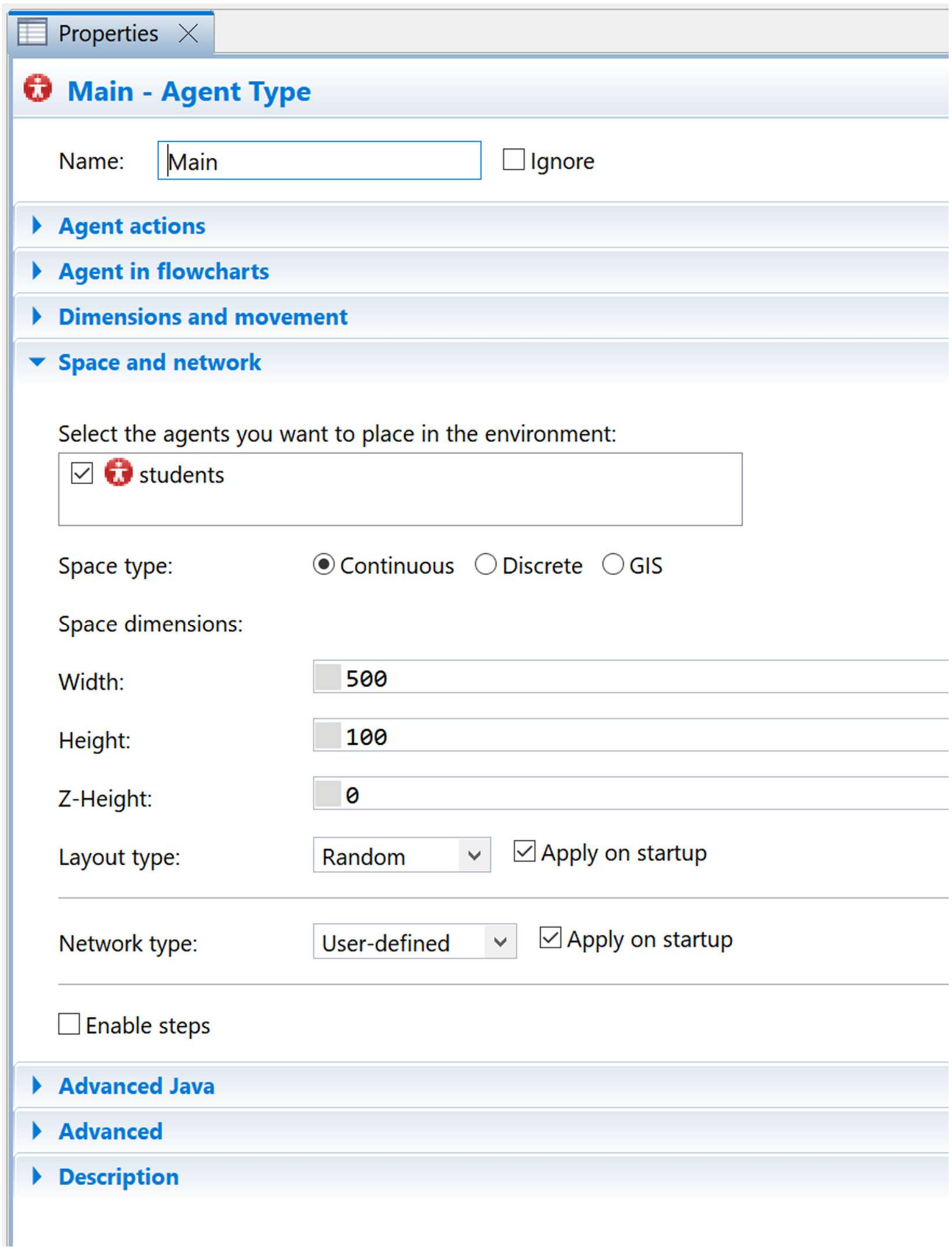


FIGURE 44. IN "MAIN - AGENT TYPE" WINDOW, "PROPERTIES" TAB, "SPACE AND NETWORK" SECTION, "LAYOUT TYPE:" SET TO "RANDOM"

Selecting the "students_presentation - Agent Presentation" (by clicking the person icon), within its "properties" tab, under the "Advanced" section, the "Draw agent with offset to this position" checkbox was checked". This will display each agent at a distinct location in the simulation.

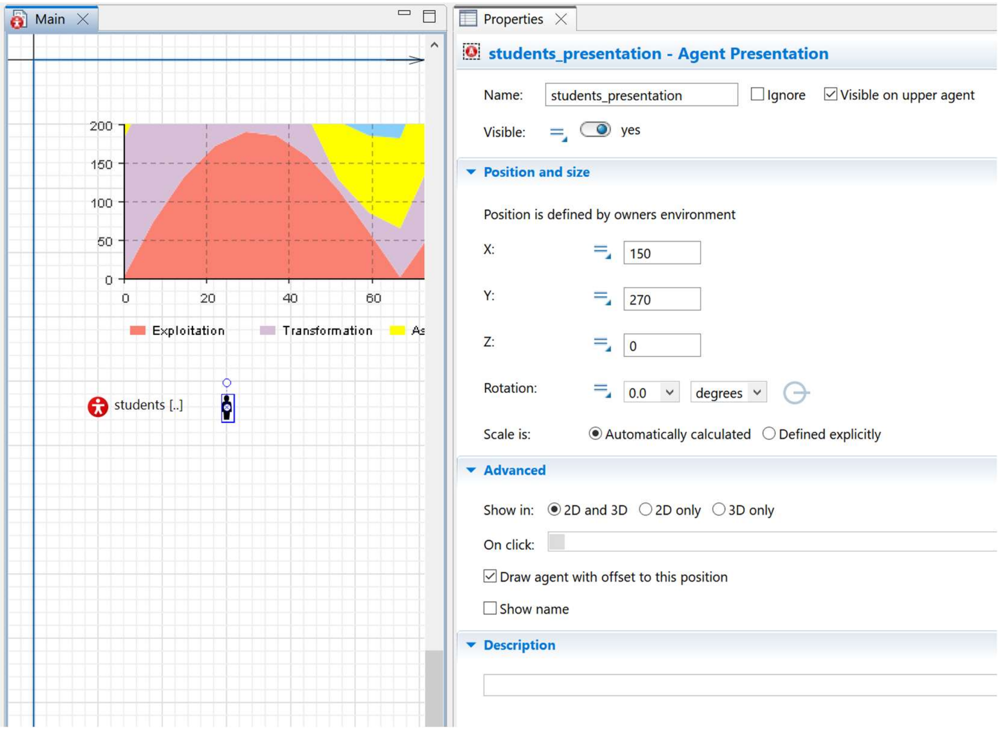


FIGURE 45. IN "MAIN - AGENT TYPE" WINDOW, SELECTING "STUDENTS_PRESENTATION - AGENT PRESENTATION" ICON, "PROPERTIES" TAB, "ADVANCE" SECTION, "DRAW AGENT WITH OFFSET TO THIS POSITION" CHECKED

Selecting the "students - Student" in the "Main - agent type" window, within its "properties" tab, the "Population is:" radio button list is selected to "Loaded from database" and its dropdown box is set to the data loaded into the database (See "6. Input Data" section for further information). This will load data from a database into the simulation. The "Mode" radio button list is selected to "One agent per database record". This will create an agent for each record in the database. In the "Agent parameter mapping:" table, each record maps a "Parameter" from the "Student - agent type" to a "Column" from the database. Here, the parameter rates are mapped to their corresponding database rate. Statistics count the students for each different ACAP state. Thus, in "Statistics" section, there is a statistic for each ACAP state whose "Name:" textfield is set to the name of the ACAP state, the "Type:" radio button is set to "count", and the "Condition:" textfield is set to the instruction "item.inState (Student." name of the ACAP state ")". These statistics can then be used for graphs and other visualisations.

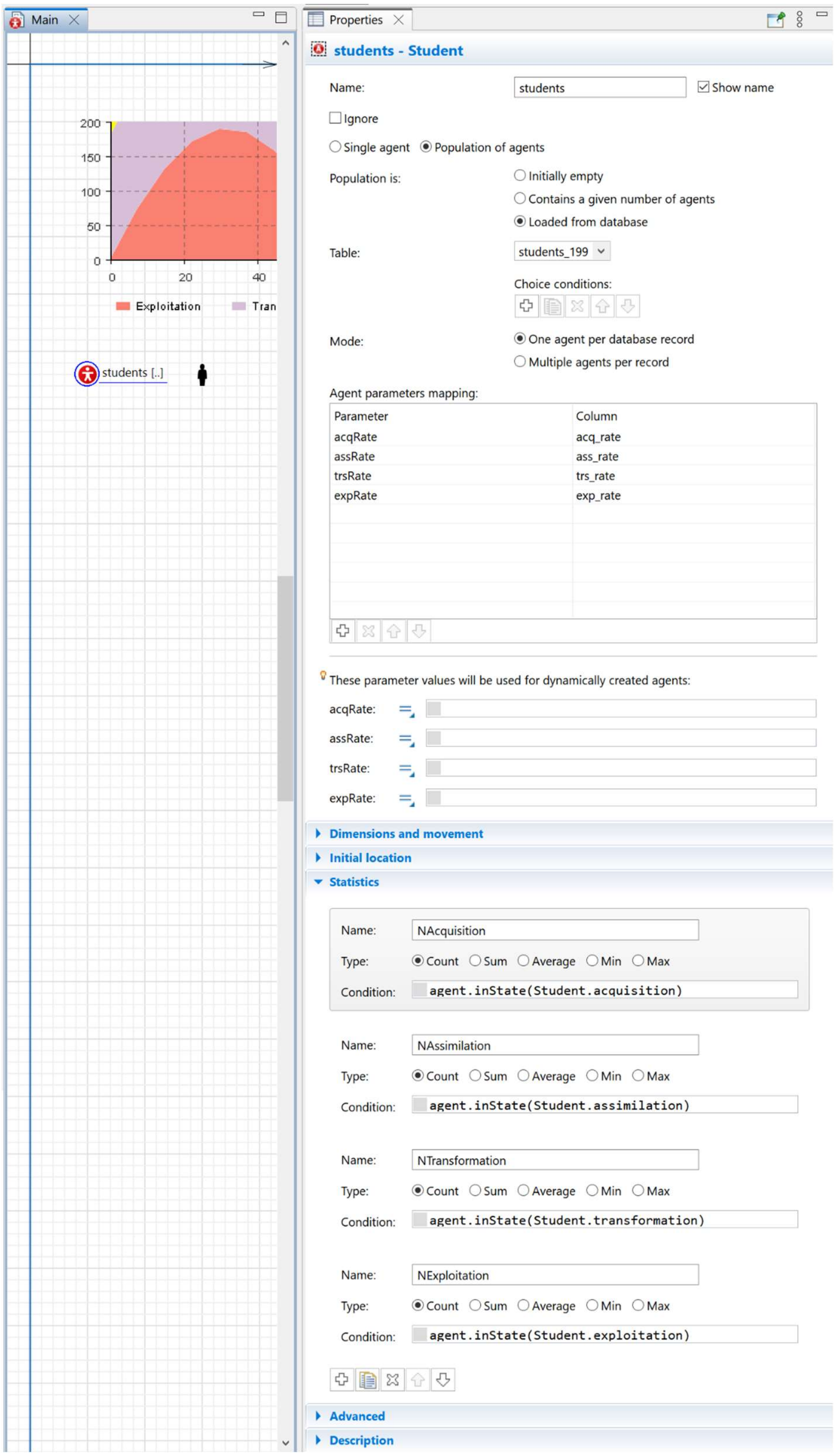


FIGURE 46. IN THE "MAIN - AGENT TYPE" WINDOW, SELECTING THE "STUDENT" ICON, "PROPERTIES" TAB, THE "STATISTICS" SECTION HAS ALL THE DIFFERENT STATES BEING COUNTED.

Student Model

In the “Student - agent type” window, the students’ ACAP flowchart is modelled. Following each state, the transition is given its corresponding rate parameter. For example, selecting the transition between the “Acquisition” and “Assimilation”, in the “Properties” tab, in the “Transition” section, the “Triggered by:” dropdown box is set to “Rate”, and the “Rate:” textfield is set to the “acquisitionRate” parameter.

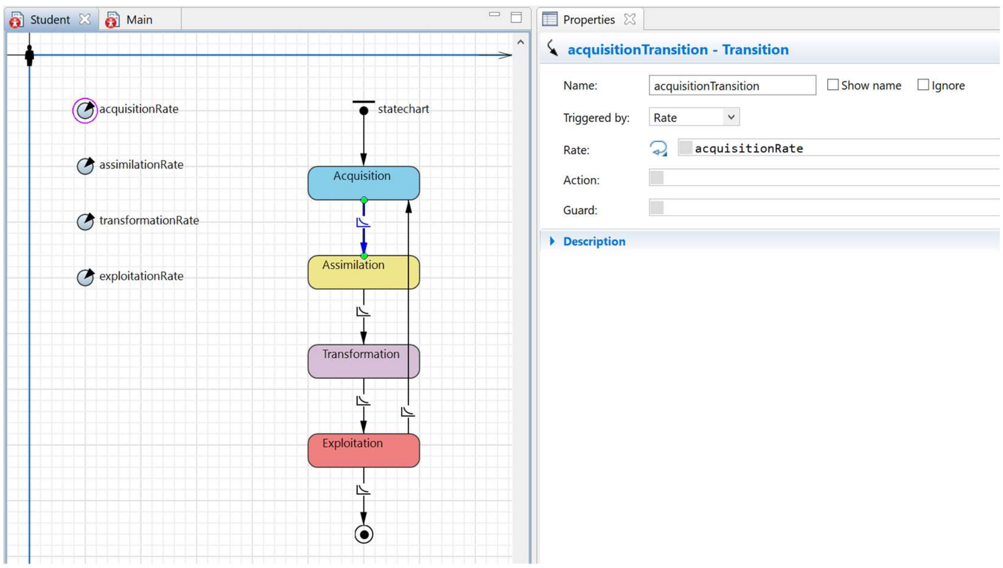


FIGURE 47. IN “STUDENT - AGENT TYPE” WINDOW, SELECTING “ACQUISTIONTRANSITION - TRANSITION” ARROW, “PROPERTIES” TAB, “ACQUISTIONTRANSITION - TRANSITION” SECTION, “TRIGGERED BY:” SET TO “RATE”, “RATE:” SET TO “ACQUISITIONRATE” PARAMETER

The spillover rate is modelled as an arrow from the “Exploitation” to “Acquisition” state. The “Rate:” can be set to different fixed values which represent whether students speak to one another.

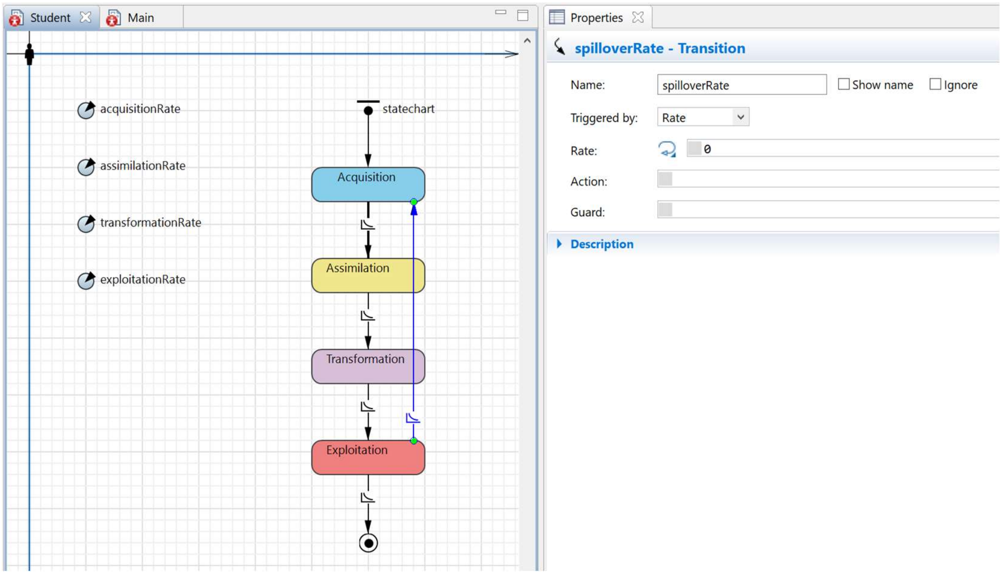


FIGURE 48. IN "STUDENT - AGENT TYPE" WINDOW, SELECTING "SPILLOVERRATE - TRANSITION" ARROW, "PROPERTIES" TAB, "SPILLOVERRATE - TRANSITION" SECTION, "TRIGGERED BY:" SET TO "RATE", "RATE:" SET TO A FIXED VALUE REPRESENTING STUDENTS INTERACTING WITH ONE ANOTHER.

6. Input Data

The input data used came from Dolmark (2020). The risk was deemed "negligible" and the UTS ethics committee approved using this data for this experiment. The input data for this experiment is quantitative. The original dataset contained anonymous responses to a web survey using Likert type scales. Participants' information such as name and date of birth were not recorded. For further information about the data collection process, please refer to Dolmark (2020). Some of the items pertained to an ACAP capability which is either Acquisition, Assimilation, Transformation, Exploitation. The responses were used to calculate for each capability the median and then the rate for each student.

7. Submodels

There are no important sub-models for this experiment.

6.3.4 Implementation: Execution simulation

Setting up the simulation

The simulation was set up in AnyLogic 8 Personal Learning Edition 8.8.1 (Build: 8.8.1.202210270952 x64). Three simulations were run for 180 minutes simulation time using the data from Dolmark (2020):

1. A simulation with a spillover rate set to 0 was run to mimic a lesson taught without any student interactions. This simulation provides a baseline to compare other simulations with.
2. Another simulation with a spillover rate to 1 was also run. While this spillover rate may not be realistic, setting it to such theoretical value allows us to observe what happens with extreme values. This is one of the advantages and purposes of using ABM.
3. A third "average of the mill" was run with a spillover rate to 0.5. This simulation is run to observe if any average spillover rate creates any observable phenomena of interest.

Simulation Results with spillover rate = 0

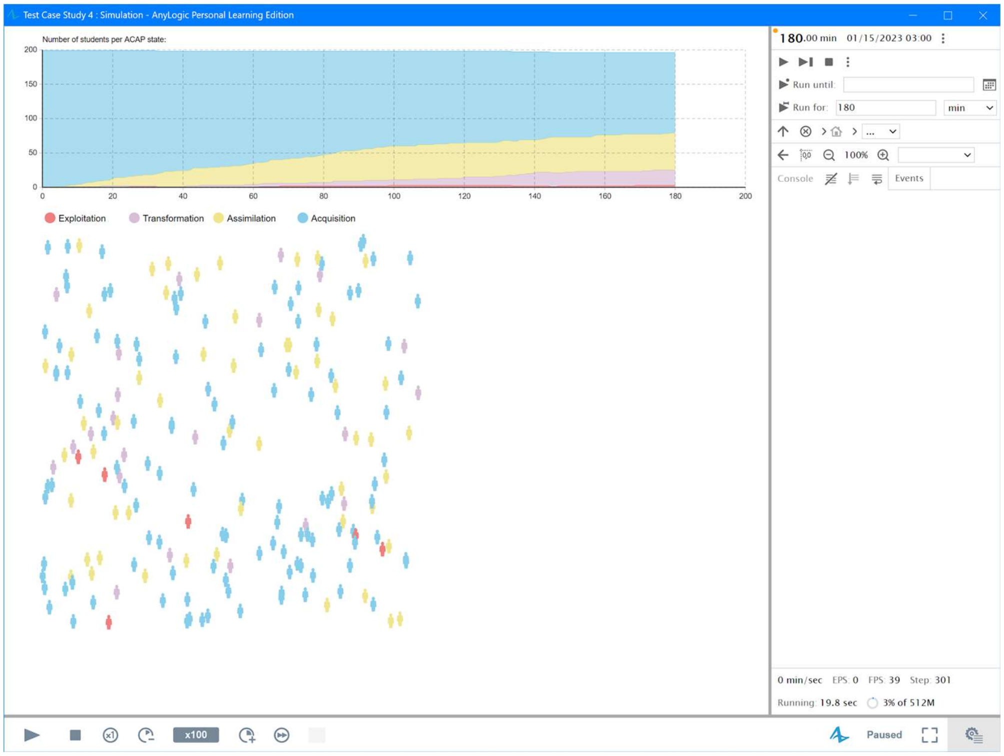


FIGURE 49. SIMULATION RUN WITH SPILLOVER RATE SET TO 0.

While very few students have achieved the Exploitation phase; most remain in the Acquisition phase.

Simulation Results with spillover rate = 1

The first simulation run was with a spillover rate set to 1 to mimic a lesson taught with maximum student interactions. While this spillover rate may not be realistic, setting the spillover rate to 1 allows us to observe the experiment with extreme parameters.

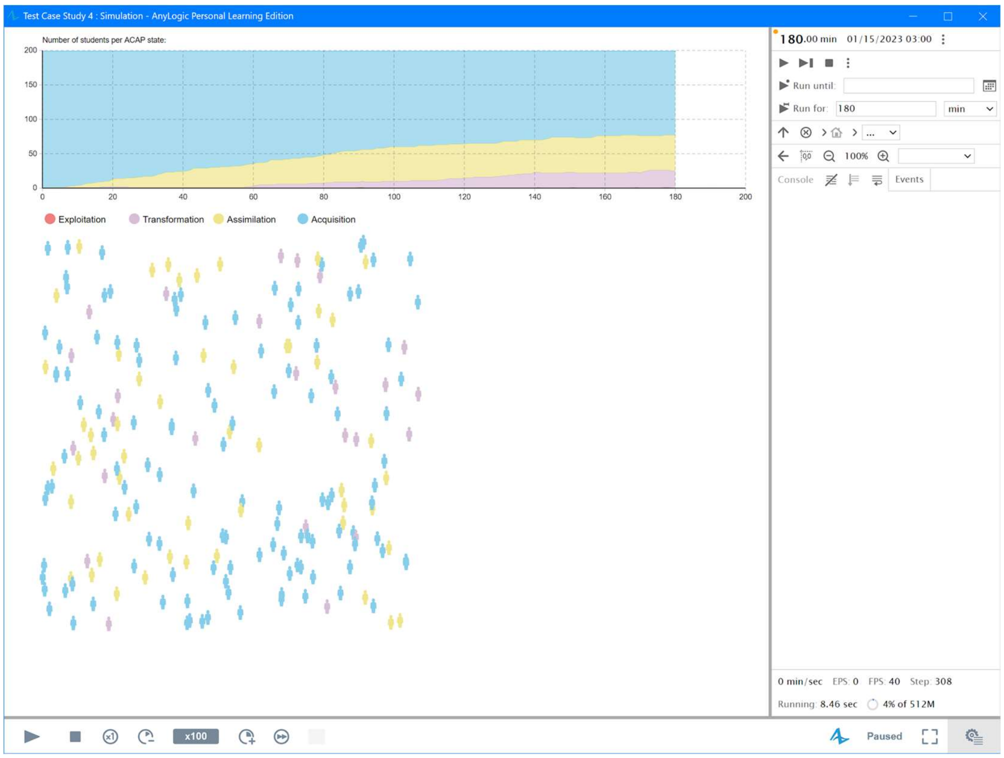


FIGURE 50. SIMULATION RUN WITH SPILLOVER RATE SET TO 1.

With a spillover rate set to 1, no student is in the Exploitation phase after 180 minutes. It should be mentioned that during the simulation some students reached Exploitation, however, they would return to the Acquisition phase.

Simulation Results with spillover rate = 0.5

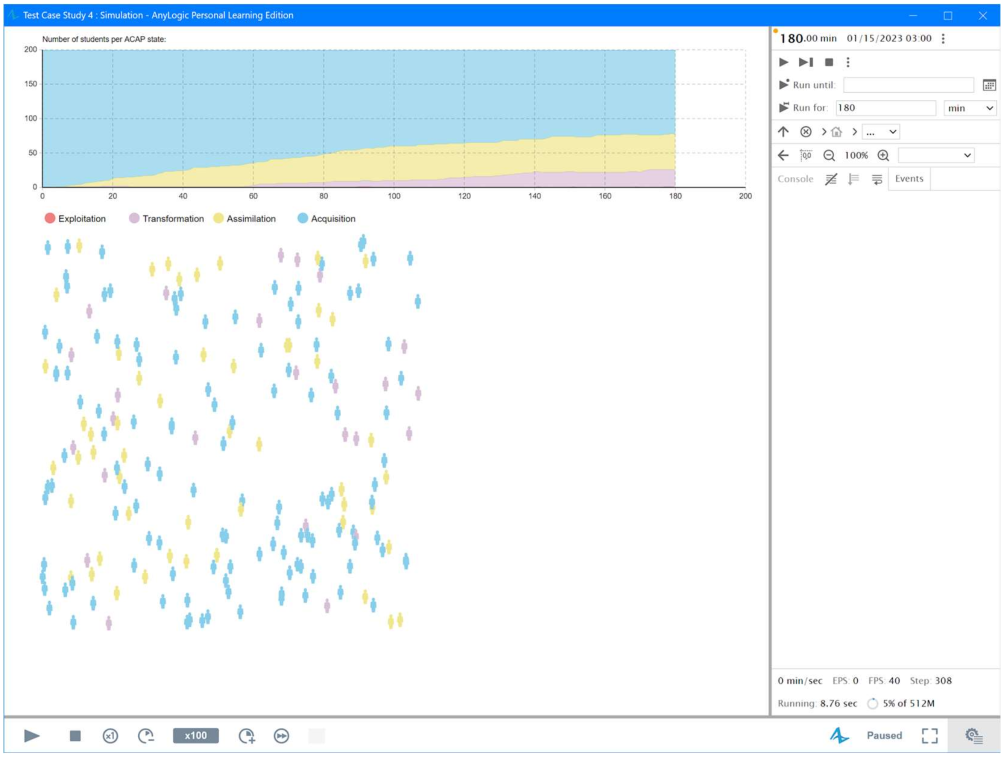


FIGURE 51. SIMULATION RUN WITH SPILLOVER RATE SET TO 0.5.

With a spillover rate set to 0.5, no student is in the Exploitation phase. Again, students who reached Exploitation would return to the Acquisition phase.

6.4 Discussion and Implications of the Results

6.4.1 Hypothesis Results

Hypothesis 1a: Interactions between individuals enhances organisational knowledge transfer.

Hypothesis 1b: Interactions between individuals diminished organisational knowledge transfer.

Hypothesis 1b has been validated, and thus leaving **hypothesis 1a** unvalidated. Organisation knowledge transfer slows down when individuals interact. A comparison of the results shows that when individuals interact that their ACAP returns from Exploitation to Acquisition.

6.4.2 Discussion of Results

Hypothesis 1b validation means many different things.

First, it appears that if humans are always learning, any extra information will cause an individual to return to the acquisition phase and begin the process of absorbing knowledge. While the theory is that all ACAP capability happens at once, it can also be difficult for an individual to listen and work at the same time.

This suggests that students or workers may need some time alone to reach the exploitation phase. While homework may fulfil this role, as a lesson it is usually a lecture and a tutorial (which do not happen in succession), therefore, when this homework is performed it may have affected students differently. This may not require an ABM as this could simply be calculated from individual metrics.

Second, these results suggest that students will need more than just 3 hours of lessons each week to learn. While UTS informs students that extra homework is needed to complete a lesson, how much is and can be determined by a student. Again, this may not require an ABM for this.

These observations are applicable to industry as well. If interactions between organisational members are detrimental to exploiting or applying knowledge, then spending too much time in group discussions such as “meetings” may not be to the benefit of a business. Industry could use Key Performance

Indicator (KPI) or other measurements to calculate how much time an organisational member such as a manager spends in group discussion instead of measuring the individual.

6.4.3 Limitations

This experiment has some very big limitations. One of the first limitations was that the design of the model was driven by data collection from Dolmark (2020). While theoretically, the design of the model should not be constrained by the data, using different already existing data sources instead of performing data collection can free up a lot of time, effort, and uncertainty about the quantity of data to be collected. Having said that, stochasticity can be used to populate the data. Another limitation was the process of analysing, designing, and implementing the ABM. There is no clearly defined process to develop an ABM. While the ROADMAP analysis and the ODD design do provide a guide for the development of an ABM, as these components are modular, they can lack cohesion which can cause "backtracking". Changing elements from the beginning stages of the development at the end of the development is very time and effort consuming as these changes can affect elements that depend on them. These changes also introduce a risk of breaking the entire product. This is not unique to ABM however without a strong development lifecycle guide, ABM remains vulnerable. Also, as mentioned before ODD can be very long in documentation. While ABM may present itself as unreliable as the results produced are theoretical, as a simulation method, it serves its purpose. While these results may be theoretical, they provide value. How these results are interpreted and applied is in the eye of the beholder. The simulation nature of ABM is not a limitation but how people interpret the results may be.

6.4.4 Further Recommendation and Conclusion

There are still a few points about the construction of an ABM in knowledge transfer that can be simplified and improved. To begin with, while the separation of an analysis and design does simplify the construction of an ABM model by separating distinct sections and components of an ABM model, the combination of the ROADMAP analysis and the ODD design may have overlapping components which causes redundancy. For example, the ROADMAP Goal Model and the ODD Objectives section can be nearly identical. More importantly, as an ABM strength is its ability to mimic the real world, this "world" needs to be modelled. This is the system with phenomena, dynamics, and causal effects that should be the first to be considered. The second item to be considered is how to model an agent. An agent is made of metrics such as parameters and variables which should represent an individual's reasons and an algorithm that represents an individual's rationale. As agents interact with the system and with each other, how these affect the systems and other agents' metrics will result in the design of these to take each other into consideration. Lastly, the third element that has been neglected is randomness. While the system and its agents should be designed to mimic the real world, the real world contains randomness which should be represented in an ABM as it can skew results. For example, in the case of the butterfly effect (as a butterfly flaps its wings in one part of the world, it will cause a hurricane in another part of the world), it is unlikely to happen as entropy would ensure that the energy produced from the flap of a wing would never be able to be more than was produced. However, randomness remains important as it can affect agents individually. For example, while the numbers drawn by the lottery may be a random series of numbers, the prize would affect an individual's behaviour based on their rationale. The injection of randomness or stochasticity in an ABM should be at points that are significant which again needs consideration. Hence, this can only happen once a basic representation has been constructed, that is a system and its agents have been modelled. Modellers should be made aware of this nuance and dependency to minimise "backtracking".

While this experiment was very simple, it still provided some very interesting results. First, the actual results produced provided insight into the dynamics of knowledge transfer. Social interactions such as group meetings can be detrimental to knowledge transfer; hence, it may be important to consider how much time is spent interacting with others when working. More importantly, while the ROADMAP analysis and ODD design may have sections that overlap, it still provides a structured process to build an ABM. This process can be reused for other experiments. The application of ABM to observe knowledge transfer creates significant opportunities. It would be of great benefit and value to pursue these.

Chapter 7: Experiment 2, ABM using ACAP and Affective States

The following experiment expands from the previous experiment by adding affective states to the ABM. It also uses a new dataset as a new data collection was performed. It answers this study's research questions 2.

7.1 Introduction

Following the previous experiment, this one expands the model using affective states during knowledge transfer. As emotions have no scientific definition (Russell & Barrett, 1999), researchers are left to fall back on other frameworks to model human "emotions". One of these frameworks is Affective States (Phye et al., 2007, p. 108). Also, as this new experiment will require data that is not available in the previously used dataset, data collection will be conducted to produce a dataset for this experiment.

7.1.1 Research Aim

The aim of this research is to investigate organisational knowledge transfer and individual affective state using individuals' characteristics and computer simulation.

7.1.2 Research Objectives

The objectives of this research are to:

- Propose a method to simulate organisational knowledge transfer and individuals' affective state from individuals' characteristics.
- Run a computer simulation of said organisational knowledge transfer and individuals' affective state.
- Observe how the data collection process affects the process of modelling an ABM.

7.1.3 Research Purpose

The purpose of this research is to offer an approach to simulating knowledge transfer and individuals' affective states during that transfer in organisations using ABM. There is currently no ABM that fulfils this purpose on the market. The other purpose is to observe how the data collection affects ABM in the simulation research design.

7.1.4 Research Significance

This research has significance for students and their mental health. This experiment models the students emotion during their learning as well as the effect of empathy on their emotions during their learning. While this may be of benefit to pedagogues as well as psychoanalysts, these benefits would penultimately affect student learning experience and outcomes.

This research would be of benefit to:

- The social media industry could use this approach with their data to simulate and predict how their users feel as they consume information from social media platforms.
- Management could use this approach to model knowledge transfer and individual affective states in their organisation. This could allow forecasting, and thus create better planning from managers, decision makers and anyone who has substantial power internally.
- The education industry would use this to model and observe how their students will feel at the start of a course rather than having to wait to observe and react accordingly.
- The IT and AI discipline would benefit from another use for ABM.
- Students, employees and other knowledge recipients would also benefit from this by the trickling effect from other stakeholders.
- Academia will of course benefit from further knowledge contribution.

7.2 Literature Review

7.2.1 Learning Emotions and Affective States

Chapter 6 summarised and articulated knowledge transfer and its barriers. It described learning as the ACAP framework in detail. For further information about ACAP, see chapter 2 and 3. However, emotions are important to learning (Pekrun et al., 2011). For further information about emotions and affective states, see chapter 3. While emotions are spoken about in common language, they are yet not well defined (De Houwer & Hughes, 2019; Russell & Barrett, 1999). As words describing emotions differ between languages, there has been no scientific definition for emotions (Russell & Barrett, 1999). Among the different frameworks to address this problem of emotions, there is one called Affective States. Phye et al. (2007, p. 108) defines a framework made of two dimensions with valence pertains to whether an individual feels positive or negative, activation is also referred to as Motivation (Feldman Barrett & Russell, 1998; Phye et al., 2007, p. 108; Russell & Barrett, 1999).

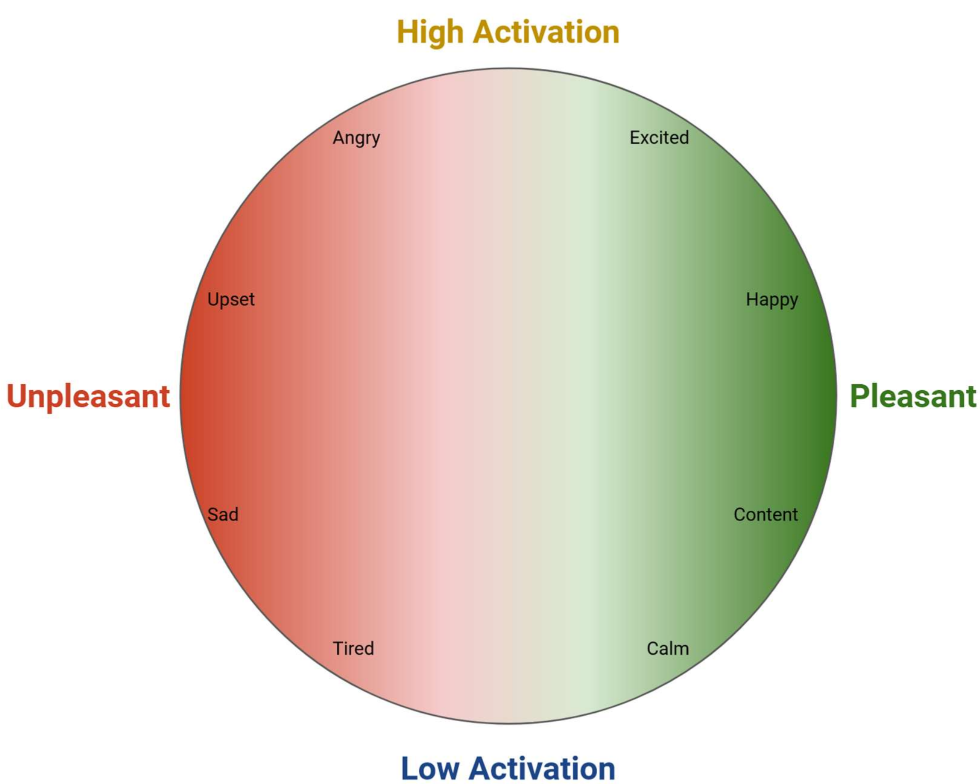


FIGURE 52. SEMANTIC STRUCTURE OF AFFECT.

Pekrun et al. (2011) offers a conceptualisation of affective states based on the timing of the learning activity. This allows translation of emotions into affective states relating to the time of the activity being the process of absorbing knowledge or ACAP (Pekrun et al., 2011).

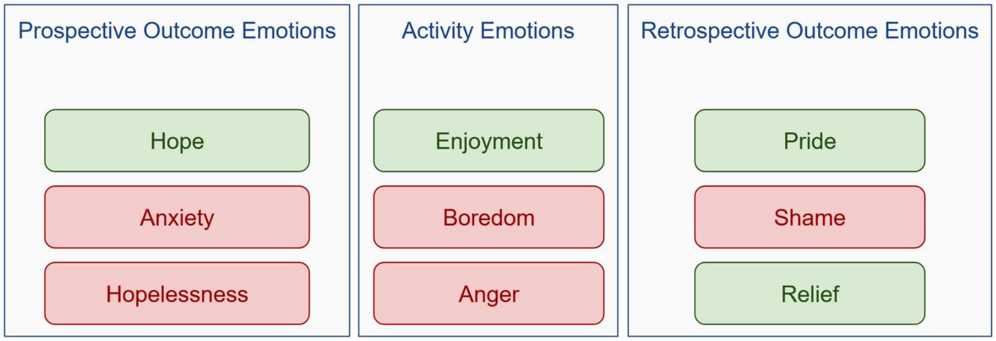


FIGURE 53. LEARNING EMOTIONS BASED ON THE TIMING TO THE ACTIVITY.

This allows to place an individual's state of valence and motivation (or activation) at different moments in the ACAP narrative from its start to its end.

7.2.2 Empathy: Cognitive Empathy

Empathy has many different definitions which all share a common consensus about it denoting the imaginative or intellectual comprehension of another person’s state of mind or condition (Hogan, 1969). It is the capability to comprehend another person’s feelings and their causes (Carré et al., 2013). Empathy is considered a key to moral development (Higgins, 1997; Hogan, 1969). Among the different frameworks for empathy, all of them share the concept of cognitive empathy. Cognitive empathy is the capability to understand another’s feeling (Carré et al., 2013). Cognitive empathy can be viewed as the ceiling that an individual can feel at any point in time. Whatever other concepts these frameworks may have, the point is that a person's reaction or empathy towards another or context may be only circumstantial.

7.2.3 Data Collection and Model Conceptualisation in Simulation Research Design

In the simulation research design proposed by Banks et al. (2005), Model Conceptualisation and Data Collection happen at the same time. And yet, there exists a dependency between the model and data. Banks et al. (2005) proposes to begin data collection as soon as possible to make up for any changes in the model. As the previous experiment used an already existing dataset, this new experiment offers the opportunity to observe the process of data collection and report any constraints discovered during the process.

7.2.4 Research Gap

As these are currently limited to no method to simulate knowledge transfer (with the exception of course of this research), there is even a greater lack of method to simulate knowledge transfer and emotions. This experiment addresses this. There is also not enough clarity regarding interactions between data collection and model conceptualisation within the simulation research design proposed by Banks et al. (2005).

7.2.5 Research Questions

Following the previous experiment, here are a new set of research questions:

RQ2: Does cognitive empathy affect affective states?

7.2.6 Scope

The scope of this experiment is to model agents affective state during the ACAP process in an ABM and observe the effect of cognitive empathy whether absent or existing on an agents affective state. This experiment 2 build on from experiment 1 by reusing the ACAP framework. Similarly to experiment 1, students from university or any education institution are ideal population to collect data from as they are actively absorbing which is ACAP and transferring knowledge.

7.2.7 Hypothesis Development

Here are the hypotheses developed from the research questions.

RQ2: Does cognitive empathy affect affective states?

As students absorb knowledge, it is reasonable for them to also absorb collective affective states. There is a recursion here where the individual affective states also contribute to the collective affective state.

Hypothesis 2: Cognitive empathy affects an individual's and collective affective states.

7.3 Methodology: Agent Based Modelling

7.3.1 Analysis: Role Oriented Analysis and Design for Multi-Agent Programming (ROADMAP) method

The ROADMAP analysis method has been merged with the following ODD documentation as the latter is extensive enough. The scenario analysis that was over complicated and redundant has been dropped.

7.3.2 Research Model: Overview, Design concept, and Detail (ODD)

1. Purpose

The purpose of this study is to model individuals' affective states during knowledge transfer in an organisation. The development of a framework to run said simulation would validate the variables that affect knowledge transfer in individuals and the environment as well as other variables or factors that affect individuals and organisations. Using ABM to simulate knowledge transfer in organisations may also be used as a means of forecasting.

2. Entities, Variables, and Parameters

ACAP, as the dynamic capability to learn, is a construct that is formed by many different measurable variables. Among the previous work on ACAP and neighbouring disciplines, some authors stand out more than others. Ajzen (2011) in his revision of his theory, admits to missing affective states from Phye et al. (2007, p. 108). As this study builds upon different fields, it requires borrowing elements from previous literature. In the following table are all the concepts, their description and citations, and if these are constructed there are also entities, calculated variables or measured parameters.

TABLE 23. LIST OF ENTITIES, VARIABLES AND PARAMETERS FROM PREVIOUS LITERATURE

Name	Description	Parameter, Variable, or Entity
Individuals		
Knowledge Recipient	Recipients of external knowledge (Szulanski, 1996).	Agent
Absorptive Capacity	Cohen and Levinthal (1990) first introduced the concept of ACAP as an organisation's capability to absorb knowledge. While ACAP is popular for organisations, research has used it at an individual level (Lowik et al., 2017)	Construct
Recognition	Scholars have often included value recognition with Acquisition (Todorova & Durisin, 2007), it is supported to be another capability along with the four capabilities of ACAP (Cuervo-Cazurra & Rui, 2017; Todorova & Durisin, 2007).	Parameter
Acquisition	Acquisition is the first capability where the object of knowledge is acquired (Zahra & George, 2002). Scholars have often included value recognition with Acquisition (Todorova & Durisin, 2007). Some support that this is an independent capability from acquisition (Cuervo-Cazurra & Rui, 2017; Todorova & Durisin, 2007), while others	Parameter

	argue the difference between recognising the need from value (Cuervo-Cazurra & Rui, 2017).	
Acquire	Acquire in this experiment represents the beginning of the knowledge absorption ACAP process. This is made of recognition and acquisition of ACAP.	Construct
Assimilation	Assimilation is defined as the capability to extract knowledge from an object (Zahra & George, 2002).	Parameter
Transformation	Transformation is the capability to reconfigure its knowledge process to connect it with prior knowledge (Zahra & George, 2002). It has been argued that Assimilation and Transformation are separate capabilities (Jansen et al., 2005; Todorova & Durisin, 2007).	Parameter
Assimilate	Assimilate in this experiment represents the climax of the knowledge absorption ACAP process. This is made of assimilation and transformation of ACAP.	Construct
Exploitation	In exploitation, knowledge is used and its value is returned (Zahra & George, 2002).	Parameter
Exploit	Exploit in this experiment represents the climax of the knowledge absorption ACAP process. This is made of exploitation of ACAP.	Construct

Affective State	Phye et al. (2007, p. 108) to define different states of affection, proposed a two-dimension approach with valence described as pleasantness and activation (Russell & Barrett, 1999; Tellegen & Watson, 1999).	Construct
Valence	Affective state dimension of valence pertains to pleasantness or hedonic tone (Feldman Barrett & Russell, 1998; Phye et al., 2007, p. 108; Russell & Barrett, 1999).	Variable
Motivation (Activation)	Affective state dimension of activation refers to energy, motivation (Feldman Barrett & Russell, 1998; Phye et al., 2007, p. 108; Russell & Barrett, 1999). This state of activation can be used to measure.	Variable
Collective Affective State	Collective affective state refers to the valence and activation that a collective has obtained.	Construct
Collective Valence	This refers to the whole valence of a group.	Variable
Collective Motivation (Activation)	This refers to the whole activation or motivation of a group.	Variable
Empathy	Among the different definitions for Empathy, there is a consensus that it denotes the imaginative or intellectual comprehension of another person's state of mind or condition (Hogan, 1969). Empathy has been considered as the cognitive ability and affective trait that is respectively the capacity to	Parameter

	comprehend (Hogan, 1969) or to experience (Bryant, 1982) another's emotions (Jolliffe & Farrington, 2006; Marshall et al., 1995). It is considered a unique ability as it allows one to understand another person's position, as well as their feelings and their causes (Carré et al., 2013).	
Cognitive Empathy	Cognitive empathy is the capability to understand another's feeling (Carré et al., 2013).	Parameter
Spatial unit		
Time	The more ingrained the experience is, the more time will be needed to unlearn and relearn new knowledge (Szulanski, 2000).	Parameter

3. Process Overview and Scheduling

Following entities and variables is the overview of the process and schedule. Process modelling can be used to model activities and flow of work (International Institute of Business, 2015, p. 318). Business Process Modelling Notation is used both across business and IT as an industry-standard (International Institute of Business, 2015, pp. 320-321). As this study is heavily focused on ACAP, it has been modelled using the Business Process Modelling Notation standard.

Level 1 Business Process Diagram

A Level 1, the business process diagram breaks down the ACAP construct into three simplified activities: acquire, assimilate and exploit. Acquire is the ACAP capability of recognition and acquisition. In this instance the acquire state is the start of the knowledge absorption process. This state would be followed by acquisition rate and assimilation rate. Scholars have argued extensively about the separation of transformation from assimilation capability in ACAP, and in this experiment they are treated as the one activity of assimilation as they are very intertwined. This also keeps the level 1 business process diagram general enough to remain level 1. Higher levels of business process diagram may decouple assimilate into assimilate and transform capability, however, this is not needed here. Here, the assimilate state represents the middle of the knowledge absorption process. It would be preceded by the acquisition rate and assimilation rate and be followed by the transformation rate and exploitation rate. The final state is exploit which is where the knowledge can be exploited and applied, and refers to the end of the knowledge absorption process. This state is preceded by the transformation rate and the exploitation rate. The acquisition rate, assimilation rate, transformation rate, and exploitation rate differ for each individual knowledge recipient.

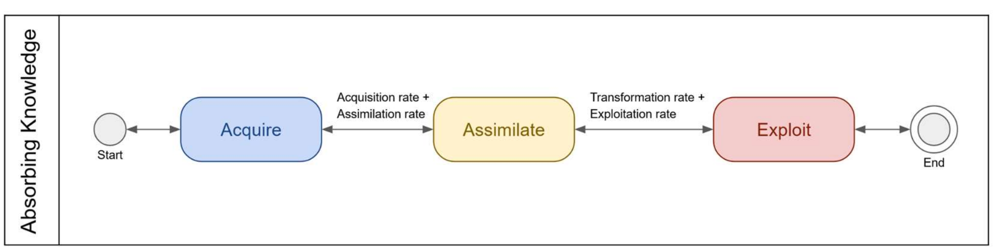


FIGURE 54. LEVEL 1 BUSINESS PROCESS DIAGRAM FOR ACAP

The section 3 process overview and scheduling will be expanded during model conceptualisation of this study. As each agent will go through the ACAP process at different rates, the model is asynchronous.

4. Design Concepts

Basic Principles

The basic principles section describes the basic ideas, theories, hypothesis, and modelling approaches of the system, agents, and context; how they relate to each other; and what field do these originate from (Grimm et al., 2020).

ACAP

While ACAP has been popular at the organisational level, it has been used at the individual level (Lowik et al., 2017). Cohen and Levinthal (1990), Zahra and George (2002), Todorova and Durisin (2007) all offered different reconceptualizations of ACAP which are all worthy. However, this study has only use for one model and not three versions of one. The ACAP process has been defined and explained previously. While ACAP has been through many revisions, there is a consistent narrative about an entity starting from not knowing to ending with knowing. While the nuances of the concepts of ACAP change with different revisions, there is a consistent narrative. As this study focuses on individuals, this ACAP narrative will be used as the foundation to define an agent's learning capability. The novelty here lies with the use of affective states.

Using Pekrun et al. (2011) learning emotions framework, affective states can be used to determine a knowledge recipient's motivation or activation, and valence when learning or the ACAP process.

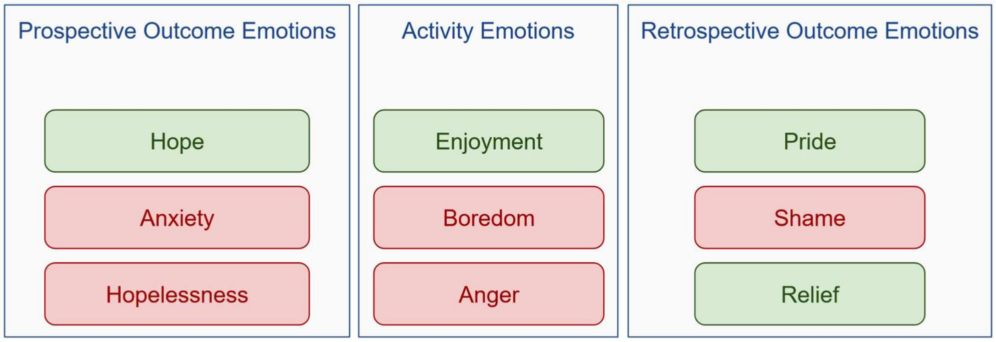


FIGURE 55. LEARNING EMOTIONS BASED ON THE TIMING TO THE ACTIVITY.

The measurement of the recipient's affective state happens at three moments in the ACAP process which are before, during, and after. These three moments of before, during, and after can be paired with the three ACAP states used in this experiment. The affective state of before is paired with the first ACAP states of acquire. The affective state of during is paired assimilate. The affective state of after is paired with the final ACAP state of exploit. The following figure illustrates the affective states according to the ACAP stages.

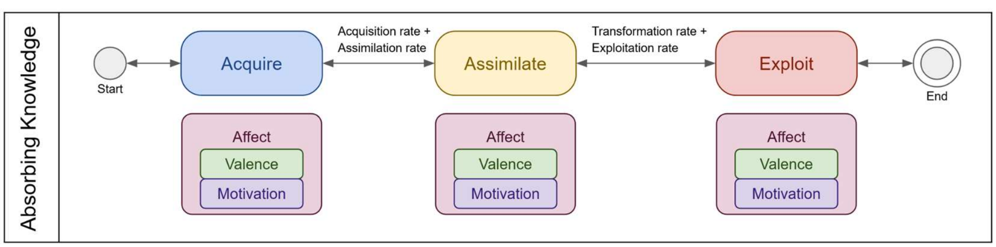


FIGURE 56. LEARNING EMOTIONS LINKED TO ACAP.

Emergence

As this is not applicable to this study, emergence will not be expanded upon.

Adaptation

The previous experiment used Savin and Egbetokun (2016) mathematical formulas for ACAP. These have not been adapted for this new experiment.

Absorptive CAPacity (ACAP)

Acquisition rate, assimilation rate, transformation rate, and exploitation rate are calculated as the average of the responses for each of the ACAP capabilities for each recipient (i).

Affective States

As stated before, Pekrun et al. (2011) offers the means to measure affective states before, during, and after a learning activity. This allows the measurement of the change of valence (v) and motivation (m) between acquire (*acq*), assimilate (*ass*), and exploit (*exp*) for each recipient. The change values are simply the difference between the previous affective state from the current affective state.

$$v_{acq \rightarrow ass} = v_{ass} - v_{acq}$$

EQUATION 3. VALENCE CHANGE VALUE FROM ACQUISITION TO ASSIMILATION

$$m_{acq \rightarrow ass} = m_{ass} - m_{acq}$$

EQUATION 4. MOTIVATION CHANGE VALUE FROM ACQUISITION TO ASSIMILATION

$$v_{ass \rightarrow exp} = v_{exp} - v_{ass}$$

EQUATION 5. VALENCE CHANGE VALUE FROM ASSIMILATION TO EXPLOITATION

$$m_{ass \rightarrow exp} = m_{exp} - m_{ass}$$

EQUATION 6. MOTIVATION CHANGE VALUE FROM ASSIMILATION TO EXPLOITATION

Spillover

As there has been new data collection for this experiment, the spillover rate can be calculated independently for each knowledge recipient. Each recipient will differ in their quantities of potential sources of information. This is assumed to be dependent on the quantity of social connections of a recipient. For the purposes of this experiment, the average number of network connections (e) a recipient (i) would define the spillover rate.

$$e = social\ network\ average$$

EQUATION 7. SOCIAL NETWORK AVERAGE

The change in the affective state of a recipient during the spillover is calculated as the difference in their affective state from the exploit state to acquire state.

$$v_{exp \to acq} = v_{acq} - v_{exp}$$

EQUATION 8. VALENCE CHANGE VALUE FROM EXPLOITATION TO ACQUISITION

$$m_{exp \to acq} = m_{acq} - m_{exp}$$

EQUATION 9. MOTIVATION CHANGE VALUE FROM EXPLOITATION TO ACQUISITION

Cognitive empathy is another parameter that is used in this experiment. Cognitive empathy (ce) as a ceiling for empathy can be used here to adapt the affective state of an agent. This cognitive empathy should be normalised to be a value within the interval of (0,1) so that it can be used as a factor. As the maximum Likert type scale value from the survey is 5, normalising cognitive empathy can be obtained by dividing the averaging of responses by 5.

$$ce = \frac{likert\ responses\ average\ for\ a\ construct}{5}$$

EQUATION 10. COGNITIVE EMPATHY AVERAGE

The empathy should also be proportional to the number of social connections (e) an agent has as these are sources of information. The change of valence (v) and motivation (m) from exploitation to acquisition ($exp \rightarrow acq$) should also be a factor in the spillover. Finally, the product of all these should be divided by the total population of agents (p) (which is here 195) to respect proportionality.

$$valence\ spillover\ = \frac{v_{exp \rightarrow acq}}{p} * \frac{e}{p} * ce$$

EQUATION 11. VALENCE SPILLOVER

$$motivation\ spillover\ = \frac{m_{exp \rightarrow acq}}{p} * \frac{e}{p} * ce$$

EQUATION 12. MOTIVATION SPILLOVER

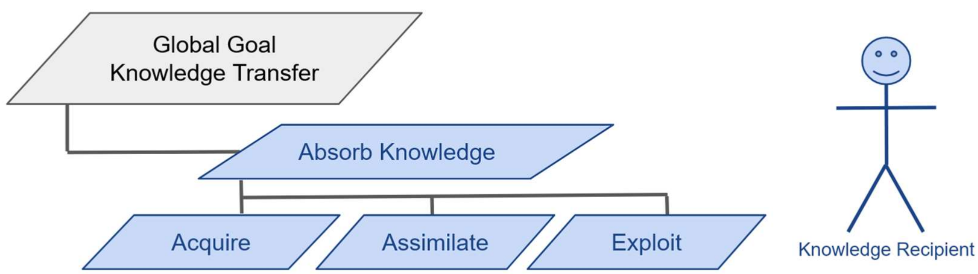
The change of affective state for a recipient during the spillover can have different factors such as Agreeableness, Information Disorder, and many more. To keep this experiment simple, these have been left out from change in the recipient's affective state. It also allows the experiment to focus on affective states rather than diverging.

Objectives

The following section addresses the objective of the model which is to model the different affective states of a student when learning.

Goal Model

A goal model for knowledge transfer was created to be generic enough to be reusable. The model starts with a global goal of knowledge transfer. This global goal is divided into several goals based on the roles that might exist in a particular context. These goals are then decomposed into sub-goals that show the different goals a role might achieve. As this research focuses on Recipient ACAP, the first role is Knowledge Recipient with Absorb Knowledge which is decomposed into acquire, assimilate which includes ACAP assimilation and transformation, and exploit. While there is a dependency in between sub-goals, for example, Exploit is dependent on Acquisition, a Knowledge Recipient can be set on the sub-goal of Acquisition without ever reaching Exploit. This is the rationale behind the decomposition of Absorb Knowledge.



This diagram is a goal model for ACAP for knowledge transfer.

FIGURE 57. GOAL MODEL FOR ACAP IN KNOWLEDGE TRANSFER

Role Model

Role models have been kept generic to be reusable. As discussed previously, the generic roles in knowledge transfer includes Knowledge Recipient. The sole constraints of the knowledge recipient here are determined by ACAP and Affective States which are Acquire, Assimilate, Exploit, Valence, and Motivation (Activation).

TABLE 24. ROLE MODEL FOR A KNOWLEDGE RECIPIENT IN THE TRANSFER OF KNOWLEDGE USING ACAP AND AFFECTIVE STATES

Role ID	KR1
Name	Knowledge Recipient
Description	Absorb knowledge from a Knowledge Source.
Responsibilities	A knowledge recipient's sole responsibility is to absorb new knowledge.
Constraints	Motivation (Activation) Valence Acquire Assimilate Exploit

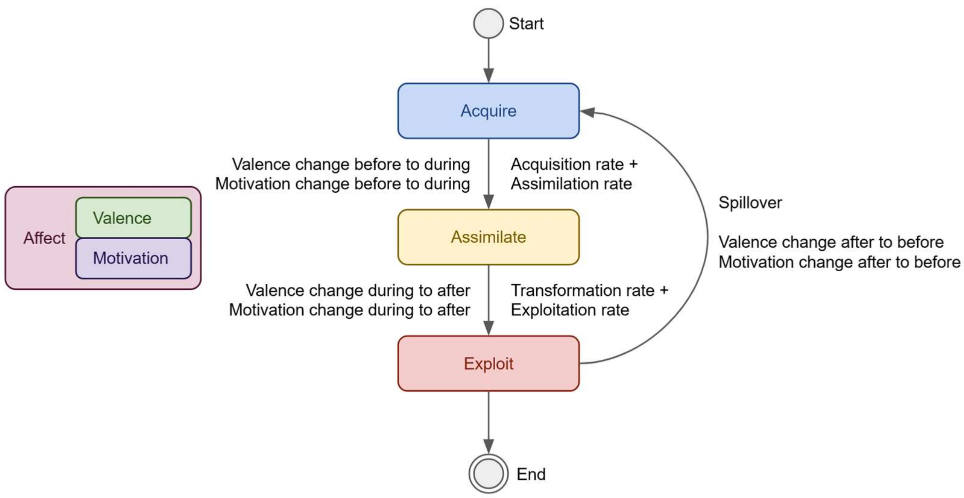
This table is the role for knowledge recipients in this experiment.

Measurements

As this study uses the ACAP and the learning emotions conceptual frameworks, it has adapted and reused instruments that have been already used for frameworks. The ACAP framework has adapted items from Jansen et al. (2005). The learning emotions used items from the Pekrun et al. (2011). This quantity of social networking can be measured using Lubben Social Networking Scale (LSNS) from James et al. (2006). While Siette et al. (2021) reviews of social network instruments make a strong argument that the context should determine the selection of the proper social network instrument, they also argue that the LSNS from James et al. (2006) is suitable for a quick snapshot. The answers for the Likert type scale for the LSNS indicate the number of network connections (*e*).

Representations

During the process of ACAP, a knowledge recipient will be in a different state. These states have already been defined as the goals of ACAP which are acquired, assimilated, and exploited. Affective States are composed of the variables valence and motivation (activation) and these will vary over time.



This diagram illustrates ACAP with affective states in the knowledge transfer.

FIGURE 58. ACAP WITH AFFECTIVE STATES IN THE KNOWLEDGE TRANSFER DIAGRAM

Calculations

Regarding the recorded answers for the LSNS. LSNS uses a Likert type scale with the answers "None", "One", "Two", "Three or four", "Five to eight", and "Nine or more". "None" is 0 connections. "One" is 1. "Two" is 2. "Three or four" can be 3 or 4, and thus it is interpreted as its minimum value of 3. "Five to eight" can be 5, 6, 7, or 8, and thus is treated here as again the minimum value of 5. "Nine or more" is 9 or more which is once more treated as minimum 9. It should be mentioned that the Qualtrics record the Likert type responses from 1 to 6 thus 1 means "None" and 6 meaning "Nine or more". Before any other calculations, the responses recorded by Qualtrics have been translated to their proper values using Excel. For the change in valence and motivation from affective state in the learning emotion, the learning emotions questionnaire allows for a snapshot of affective state before, during, and after the knowledge absorption.

The process was as followed:

1. The responses were grouped by their time relation. Or otherwise said, responses were grouped by whether they were "before" (acquire), "during" (assimilate), and "after" (exploit) the learning activities.
2. This partitioning of responses was averaged by their affective state dimension of valence and motivation. In other words, all responses regarding an affective state of positive valence were averaged together and all negative valences were averaged. The same step was performed for negative and positive motivation.
3. Following this, the average negative valence was subtracted from the average positive valence, and again, the average positive motivation was subtracted from the average negative motivation. This provided the difference from the neutral point for each dimension of the affective state.
4. Finally, the last calculations performed were as described in the Adaptation section for affective state and spillover. To reiterate what was said in Adaptation, these differences were again subtracted from one ACAP state from another. For example, subtracting the acquire valence from assimilate valence provides the valence change from acquire to assimilate. This is reproduced for other ACAP states for valence and motivation including spillover.

Other calculations that have been applied have been described in the Adaptation section. The dataset used in this experiment is from a new data collection which has been described in detail in the Data Collection section.

Learning

As this is not applicable to this study, learning will not be expanded upon.

Prediction

As this is not applicable to this study, prediction will not be expanded upon.

Sensing

As this is not applicable to this study, Sensing will not be expanded upon.

Interaction

Interactions are set by the spillover value which is set by the average of LSNS.

Activities

Activities for the knowledge recipient have merged assimilate and transform into assimilate.

TABLE 25. AGENT MODEL

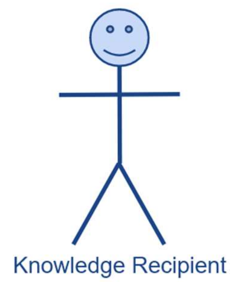
Agent ID	KR	Agent Name	Knowledge Recipient

Activity Name	Acquire
Roles Played	Knowledge Recipient
Functionality	Acquire knowledge
Precondition	Start Or Received knowledge spillover
Postcondition	Knowledge will be assimilated

Activity Name	Assimilate
Roles Played	Knowledge Recipient
Functionality	Assimilate knowledge
Precondition	Knowledge must be acquired
Postcondition	Knowledge will be transformed

Activity Name	Exploit
Roles Played	Knowledge Recipient
Functionality	Exploit knowledge
Precondition	Knowledge must be transformed
Postcondition	End Or Spillover to another knowledge recipient

Environmental Considerations

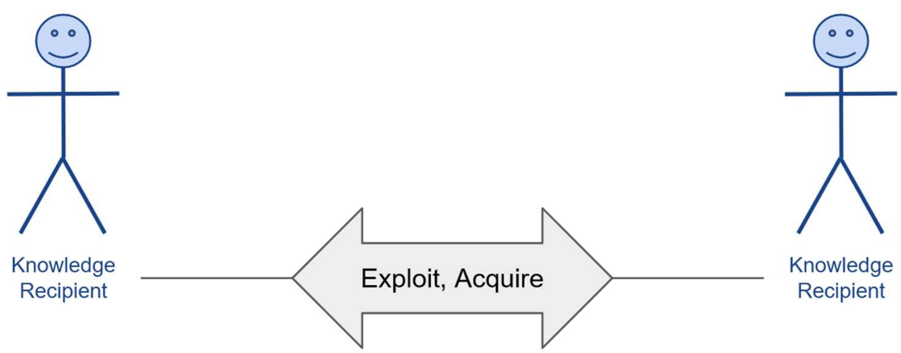


This diagram illustrates the different activities a knowledge recipient or student can perform.

FIGURE 59. ACTIVITY MODEL FOR KNOWLEDGE RECIPIENT AS A STUDENT IN A UNIVERSITY COURSE

Interactions

The interaction model details the activities in which the agents interact with (Garro & Russo, 2010).



This diagram illustrates the different interactions as activities a knowledge recipient or source can perform with another or alone.

FIGURE 60. INTERACTION MODEL FOR KNOWLEDGE RECIPIENT AS A STUDENT IN A UNIVERSITY COURSE

This experiment uses the same interaction model as the previous experiment.

Stochasticity

As this is not applicable to this study, Stochasticity will not be expanded upon.

Collectives

Cognitive empathy is only a ceiling to the affective state that an individual can empathise with. This requires the modelling of variables representing the collective affective state of the population (p). This collective state would be made of collective valence (v_p) and collective motivation (m_p). It would be the sum of all the agents' valence and motivation. As agents have different valence and motivation at different points in time, these collective variables will have to be summed at different moments in time of the absorption process.

Observation

Running the simulation will allow the observation of the fluctuation of Affective States over time giving an overall view of context and perhaps more importantly which Affective State dominates.

5. Initialization

Setting up the simulation for without cognitive empathy

For this experiment, the simulation was designed and executed using AnyLogic 8 Personal Learning Edition 8.9.0 (Build: 8.9.0.202404161236 x64). The simulation was set to minutes.

Main Model

In the “Main - agent type” window, within its “Properties” tab, under the “Space and network” section, the “Layout type:” dropdown box was set to “Random”. This will display agents at one random location in the simulation.

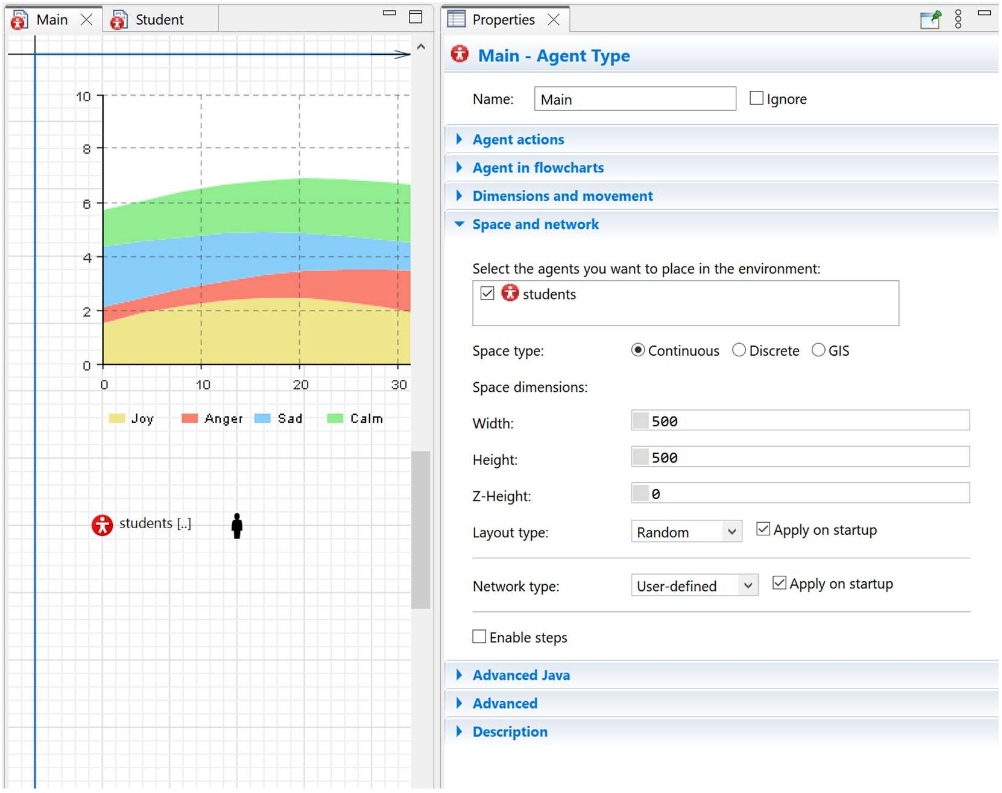


FIGURE 61. IN "MAIN - AGENT TYPE" WINDOW, "PROPERTIES" TAB, "SPACE AND NETWORK" SECTION, "LAYOUT TYPE:" SET TO "RANDOM"

Selecting the "Lesson_presentation - Agent Presentation" (by clicking the person icon), within its "properties" tab, under the "Advanced" section, the "Draw agent with offset to this position" checkbox was checked". This will display each agent at a distinct location in the simulation.

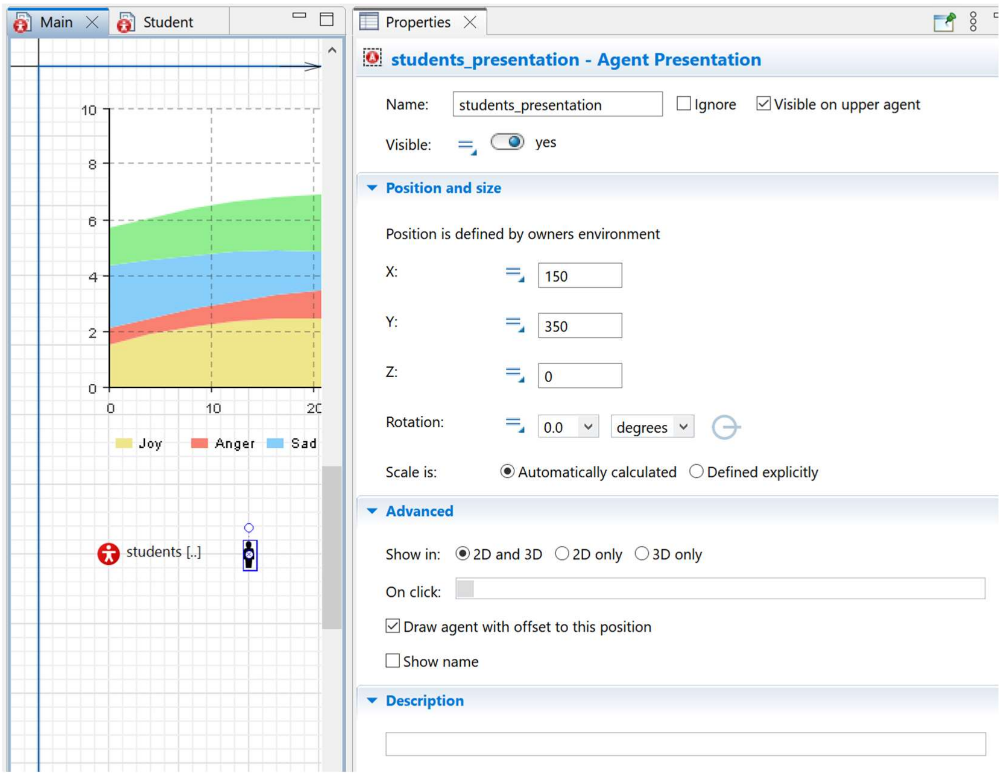
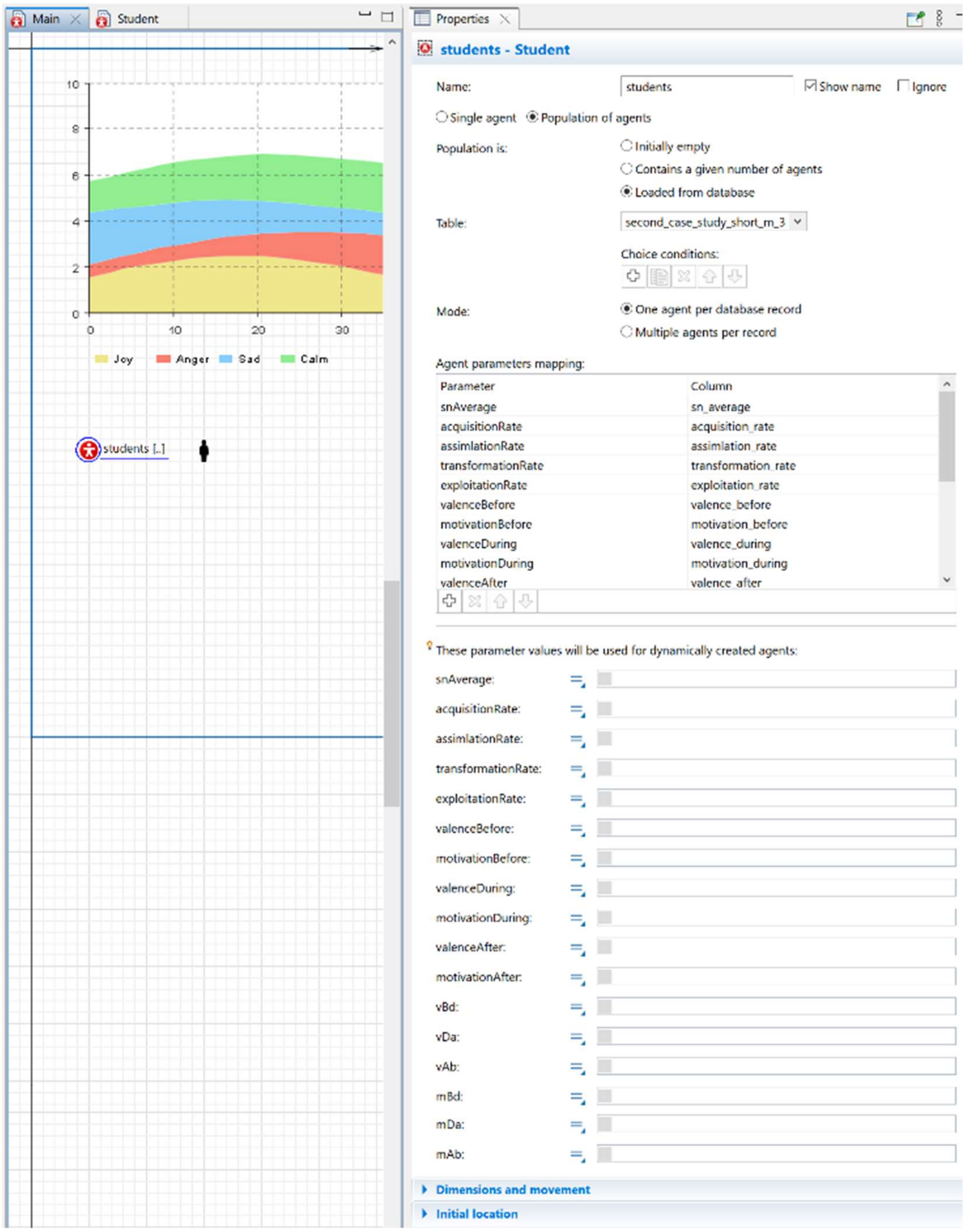


FIGURE 62. IN "MAIN - AGENT TYPE" WINDOW, SELECTING "STUDENTS_PRESENTATION - AGENT PRESENTATION" ICON, "PROPERTIES" TAB, "ADVANCE" SECTION, "DRAW AGENT WITH OFFSET TO THIS POSITION" CHECKED

Selecting the "Student" in the "Main - agent type" window, within its "properties" tab, the "Population is:" radio button list is selected to "Loaded from database" and its dropdown box is set to the data loaded into the database (see "6. Input Data" section for further information). This will load data from a database into the simulation. The "Mode" radio button list is selected to "One agent per database record". This will create an agent for each record in the database. In the "Agent parameter mapping:" table, each record maps a "Parameter" from the "Student - agent type" to a "Column" from the database. Furthermore, the parameter rates are mapped to their corresponding database rate.

Statistics count the students for each different affective state. Thus, in "Statistics" section, there is a statistic for each affective state whose "Name:" textfield is set to the name of the affective state, the "Type:" radio button is set to "count", and the "Condition:" textfield is set to the instruction "item.inState (Student." name of the affective state ")". These statistics can then be used for graphs and other visualisations.



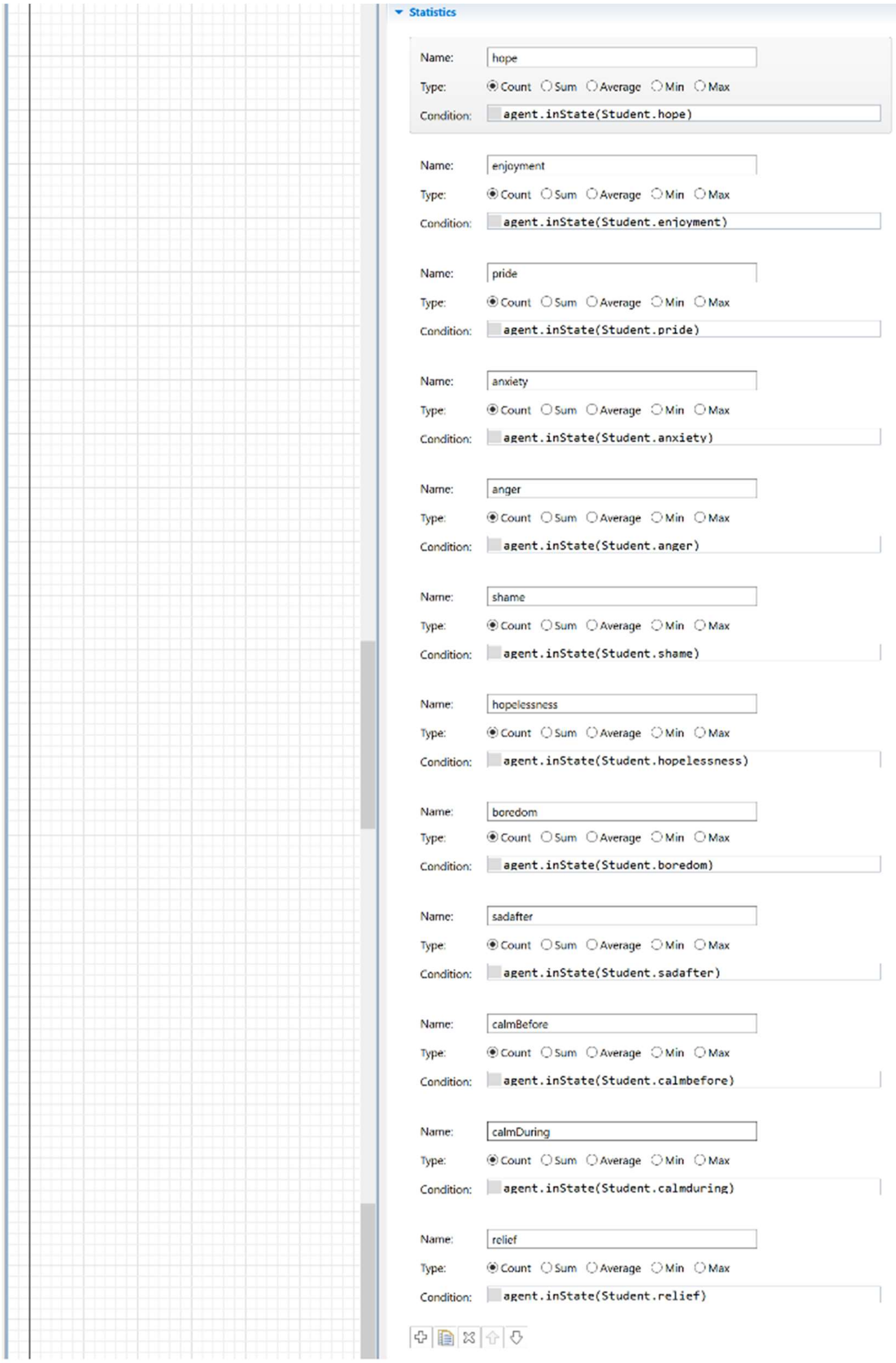


FIGURE 63. IN THE "MAIN - AGENT TYPE" WINDOW, SELECTING THE "LESSON" ICON, "PROPERTIES" TAB, THE "STATISTICS" SECTION HAS ALL THE DIFFERENT STATES BEING COUNTED.

In the "Student - agent type" window, the students' flowchart is modelled. Two variables are created which are "valence" and "motivation" which represent the dimensions of affective state. With the "valence" variable selected, in the property window, in the "Initial value:" textfield, "valenceBefore" is inputted to set the initial value of valence at the start of the simulation to the value of valenceBefore parameter. The same process is used to set the variable "motivation" to "motivationBefore".

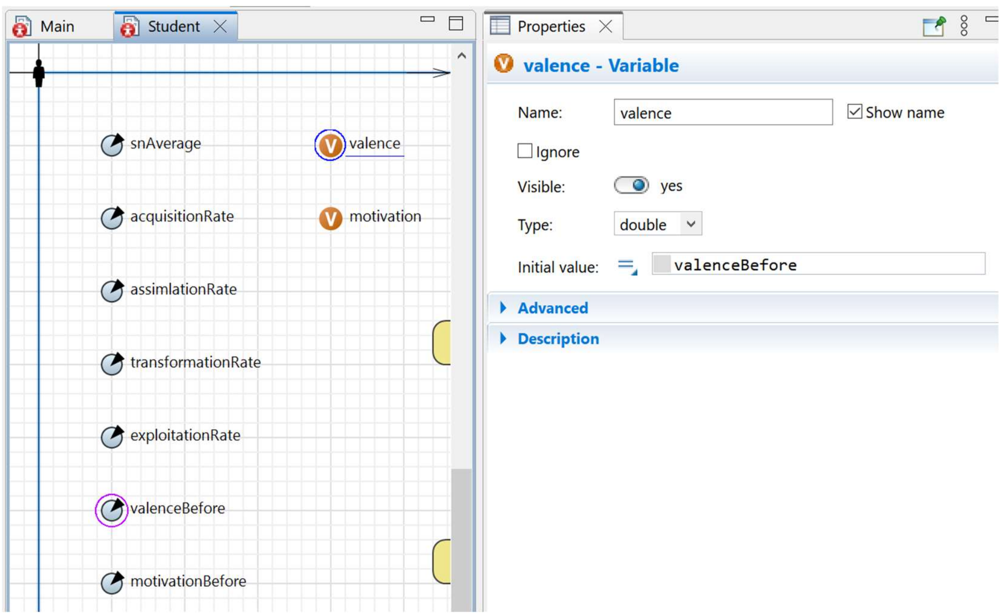


FIGURE 64. IN THE "STUDENT - AGENT TYPE" WINDOW, SELECTING "VALENCE", IN THE "PROPERTIES" TAB, INPUTTING "VALENCEBEFORE" PARAMETER IN THE "INITIAL VALUE:" TEXTFIELD.

Each ACAP state of acquire, assimilate, and exploit are split into distinct affective states. Each quadrant of affective state is modelled. There is one for positive valence and positive motivation which represents affective state joy, one for positive valence and negative motivation which is calm, one for negative valence and positive motivation which is anger, and one for negative valence and negative motivation which is sad. Each ACAP state is preceded by a branch with two transitions which each link to a branch with two transitions each. For one of these two transitions for each branch, in the property window, the option "Conditional" is selected. In the "Condition:" textfield, the condition statement to take this path is inputted. The first branch condition is set to “valence>0” while the second and third branch condition is set to “motivation>0”. This sets the branch to direct the flow to the proper affective state according to the value.

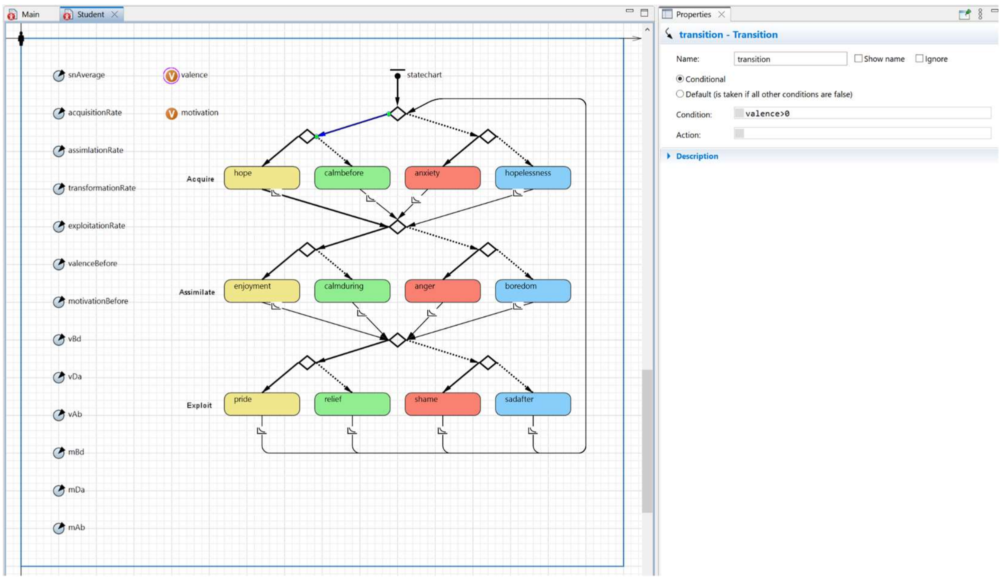


FIGURE 65. IN THE “STUDENT - AGENT TYPE” WINDOW, SELECTING A TRANSITION, IN THE “PROPERTIES” TAB, SELECTING “CONDITIONAL” AND INPUTTING THE CONDITION IN THE “CONDITION:” TEXTFIELD.

Each state is given a name and a colour representing one of the four quadrants of affective states. Red is for anger, blue is for sadness, yellow for joy, and green is for calm. More importantly, in the “Properties” tab for each state, in the “Entry action:” textfield, “shapeBody.setFillColor (“colour “)” is inputted where “colour” is set to the colour of the state so that when the simulation is executed, the agent changes colour. In the “Exit action:” textfield, the formula “valence+=parameter;motivation+=parameter;” is inputted so that the variables of valence and motivation change according to the respective “parameter”. For acquire, the parameters are “vBd” and “mBd” for valence and motivation respectively. For assimilate, “vDa” and “mDa” are used. Finally, for exploit, “vAb” and “mAb” are used.

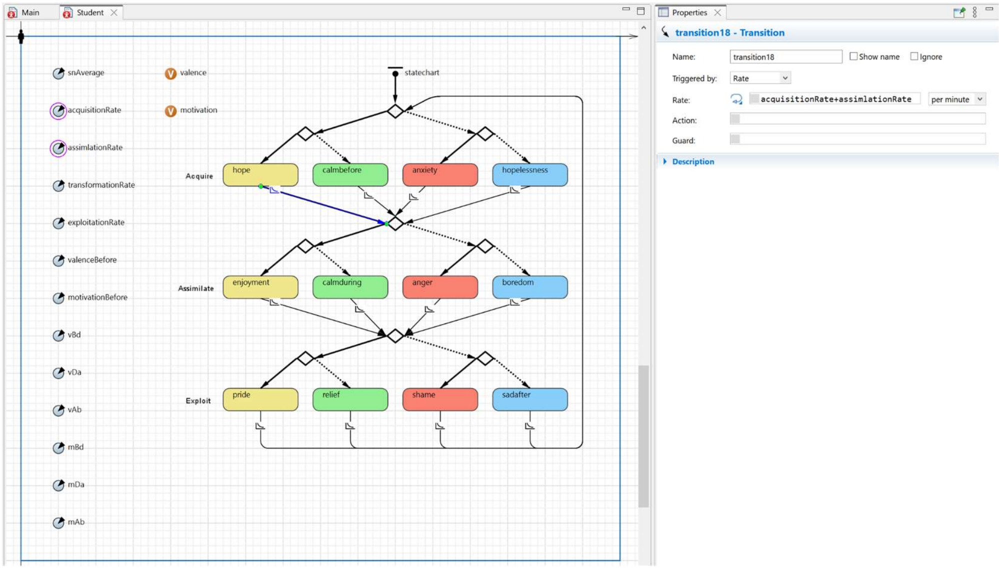


FIGURE 66. IN THE "STUDENT - AGENT TYPE" WINDOW, SELECTING A STATE, IN THE "PROPERTIES" TAB, INPUTTING THE CODE IN THE "ENTRY ACTION:" AND THE "EXIT ACTION:" TEXTFIELDS.

Following each state, the transition is given its corresponding rate parameter. For example, selecting a transition after acquire, in the "Properties" tab, in the "Transition" section, the "Triggered by:" dropdown box is set to "Rate", and the "Rate:" textfield is set to the "acquisitionRate+assimilationRate" formula. The same is performed for transitions after assimilation except the "Rate:" textfield is set to "transitionRate+exploitationRate".

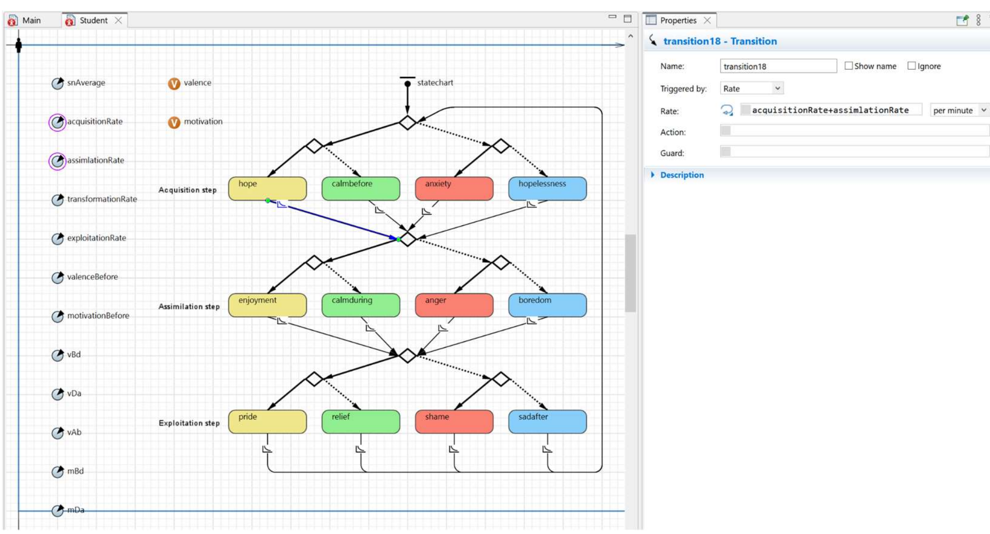


FIGURE 67. IN THE "STUDENT - AGENT TYPE" WINDOW, SELECTING A TRANSITION ARROW AFTER A STATE, "PROPERTIES" TAB, "TRANSITION" SECTION, "TRIGGERED BY:" SET TO "RATE", "RATE:" SET TO RESPECTIVE PARAMETER FORMULA

The spillover rate is modelled as an arrow from the exploit to the branch leading to the acquire. The "Rate:" is set to the parameter "snAverage" which is the average network connections of a recipient.

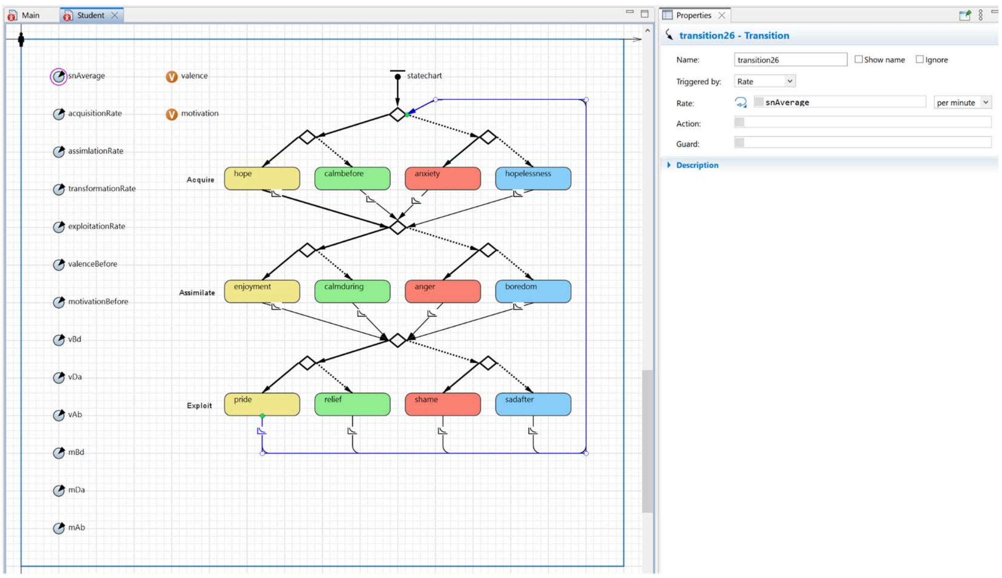


FIGURE 68. IN THE "STUDENT - AGENT TYPE" WINDOW, SELECTING A TRANSITION ARROW FROM THE EXPLOIT, "PROPERTIES" TAB, "TRANSITION" SECTION, "TRIGGERED BY:" SET TO "RATE", "RATE:" SET TO THE "SNAVERAGE" PARAMETER.

Setting up the simulation for with Cognitive Empathy

The simulation setup remains the same except there are some key differences which are listed below.

Main model

In the main model, a variable called "collectiveValence" is created which represents the collective valence. Another variable for collective motivation called "collectiveMotivation" is likewise created as well.

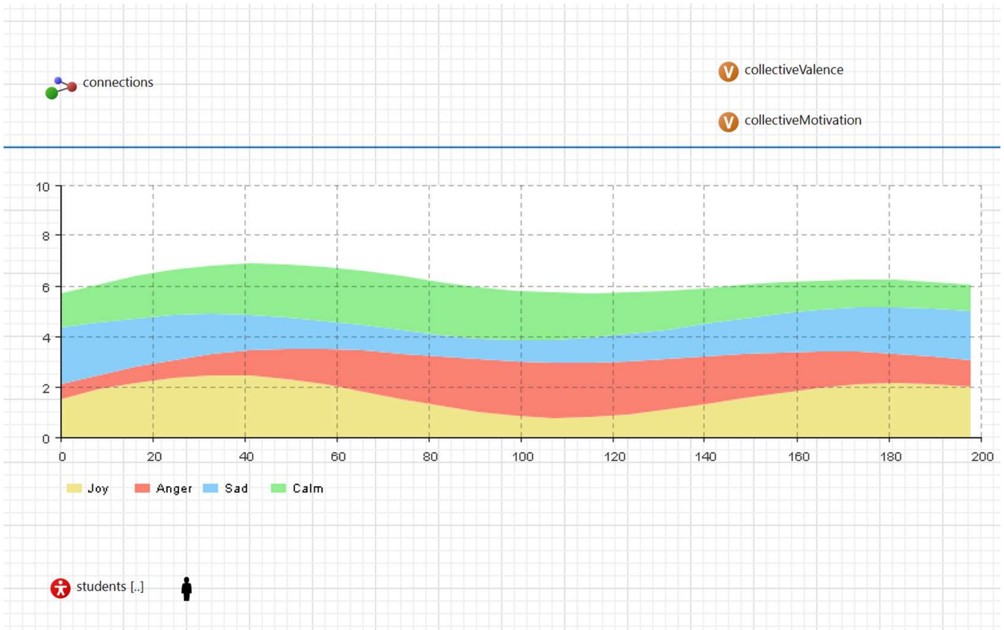


FIGURE 69. IN "MAIN - AGENT TYPE" WINDOW, COLLECTIVEVALENCE AND COLLECTIVEMOTIVATION ARE CREATED.

Student Model

In the student model, the instruction "main.collectiveValence+=valence;main.collectiveMotivation+=motivation;" is added to "Exit Action:" instruction so that the collective affective state is affected by the agents' affective states. In the transition from the exploit states to the acquire states the instruction "valence+=vAb*(main.collectiveValence/195)*(snAverage/195)*(cognitiveEmpathyAverage/5);motivation+=mAb*(main.collectiveMotivation/195)*(snAverage/195)*(cognitiveEmpathyAverage/5);" is added to the "Action:" textfield to model agents' cognitive empathy.

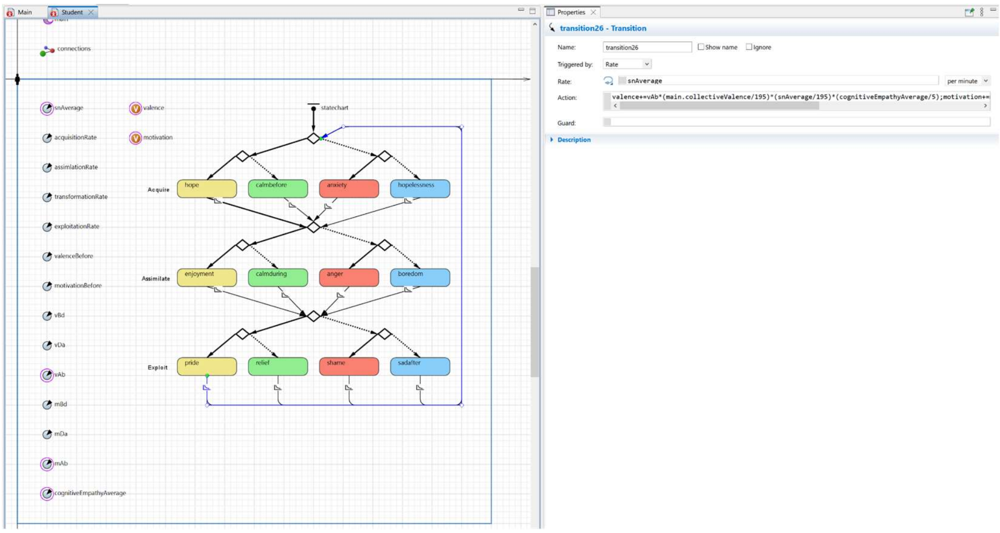


FIGURE 70. IN THE "STUDENT - AGENT TYPE" WINDOW, SELECTING A TRANSITION ARROW FROM THE EXPLOIT, "PROPERTIES" TAB, "TRANSITION" SECTION, INPUTTING THE CODE IN THE "ACTION:" TEXTFIELD.

6. Input Data

For this experiment, there were no dataset that were publicly available; therefore, a survey had to be designed and data collection had to be conducted. The details of the survey design and data collection have been provided below.

Survey Design

In simulation design, model conceptualisation and data collection happen at the same time. The input data for this experiment is quantitative. As data collection can be quite a difficult exercise, to cover any potential unforeseen gaps in the data, the survey was designed with as many items as possible. With the exception of the consent sheet and the demographic questions, the questionnaire was designed using questions from peer reviewed articles. The demographic questions were optional. The survey had been configured so that if a participant answered "Under 18" when asked "What is your age?" in the demographic question, they would be redirected to an end of survey and their response would not be recorded as it is illegal to collect data about a minor without their guardian present. LSNS originated from James et al. (2006) which can be used to provide a snapshot of an individual's social network. The Delayed Gratification Inventory (DGI) 10 item scale came from Hoerger et al. (2011) is used to measure a person's determination to delay gratification. The General Trust Scale (GTS) was from Yamagishi and Yamagishi (1994) and measures the general trust of an individual. The Protection Motivation Theory (PMT) was modified from Kim et al. (2022) to suit the scope and context of this study. It was also limited to 15 items by removing Affective Response and Behavioural Intention reasonably shorter. The term "COVID-19" in the survey item was replaced by the term "others" and the term "society" was replaced by the first-person pronoun "I", "we" or "me". Agreeableness scale originated from the Big 5 personality trait from Goldberg (1992). Extraversion, Neuroticism, Conscientiousness, and Openness were left out as Agreeableness was deemed to have an effect in networking. High agreeable individuals tend to not interact with people who are aggressive (Letzring & Adamcik, 2015; Meier et al., 2006). Cognitive Empathy was taken from Carré et al. (2013) BES-A scale. Only the items relating to Cognitive Empathy were kept as Cognitive Empathy is the ceiling to any empathy (Carré et al., 2013). Cognitive style and ACAP was taken from Lowik et al. (2017). Learning Emotions were copied from Pekrun et al. (2011). A consent sheet was supplied at the start of the survey. Participants who did not provide consent by ticking the respective checkbox were redirected to an end of survey page and their responses were not recorded. The demographic questions contained a question pertaining to the age of the participant. If the participant chose under 18 years of age, they were redirected to an end of survey response page and their responses were not recorded as it is against the law to collect data of minors without parental consent in Australia. The survey contained 111 Likert type questions in total. These were proofread and implemented into the Qualtrics Web Survey system. The survey was submitted to the UTS ethics committee. It was approved on 11 January 2024. The data collection was then allowed to commence.

Data Collection

A Likert type survey was designed and sent for approval to the UTS Ethics Committee. Once the approval had been granted, the survey had been ported onto Qualtrics becoming a web survey. The web survey did not record participants' names, date of birth, nor their address postal, IP, or otherwise to safeguard the participants identity. The other reason to keep the survey anonymous was so that participants did not feel pressured to answer the survey items with "proper" responses. In order to answer the survey, the participant had to confirm that they were at least 18 years old and provide their consent. This was done by having the survey introduce itself with a consent form which required a checkbox to be ticked to provide consent and a demographic question asking participants their age range. The checkbox on the consent form was set to unticked as default. Participants who proceeded without ticking the consent checkbox or who selected the age range "under 18 years old" were redirected to a page thanking them for their contribution and did not record their response. All responses in the survey have therefore given consent and are from people who are at least 18 years old. The web survey was distributed at UTS via a web link using email and presenting the weblink in class. The data collection was collected at UTS between 11 January 2024 (date of first response) and 15 April 2024 (date of last response). The survey collected 202 records. It should also be reported that when the survey was released a few people had raised that the survey was too long. It is a fair criticism.

Data Cleansing

Seven records have been omitted as these had missing responses. This leaves 195 usable records.

Demographic Analysis of the Data

The survey had at its beginning 4 demographic questions. All demographic questions were structured. These questions were optional. All these demographic questions also offered the option to answer "Prefer not to say" to safeguard the participants choice to not answer the question. The questions also had the option to answer "I don't know" in case the participants were unsure of what to answer.

Gender identity of the participants

The first demographic question asked the participants what gender they identify as. This question was structured with the following choices as responses: “Male”, “Female”, “Non-binary”, “Other”, as well as, “Prefer not to say” and “I don't know”. The “Other” response also contained a textfield so that participants may input their gender identity.

TABLE 26. GENDER IDENTITY RESPONSES

Answer	Number of responses	In percent
Prefer not to say	0	0.0%
Male	124	63.6%
Female	65	33.3%
Non-binary	4	2.1%
I don't know	1	0.5%
Other	1	0.5%

Surprisingly, none of the participants answered “Prefer not to say”. 1 participant answered “I don't know”. 1 other participant responded “Other” and in the supplied textfield, they answered “Gay”. 4 participants answered “non-binary” which is only 2.1% of the population made of 195 participants used for the experiment. Finally, 124 participants answered “Male” which is 63.6% of the population and 65 answered “Female” which is 33.3% of the population.

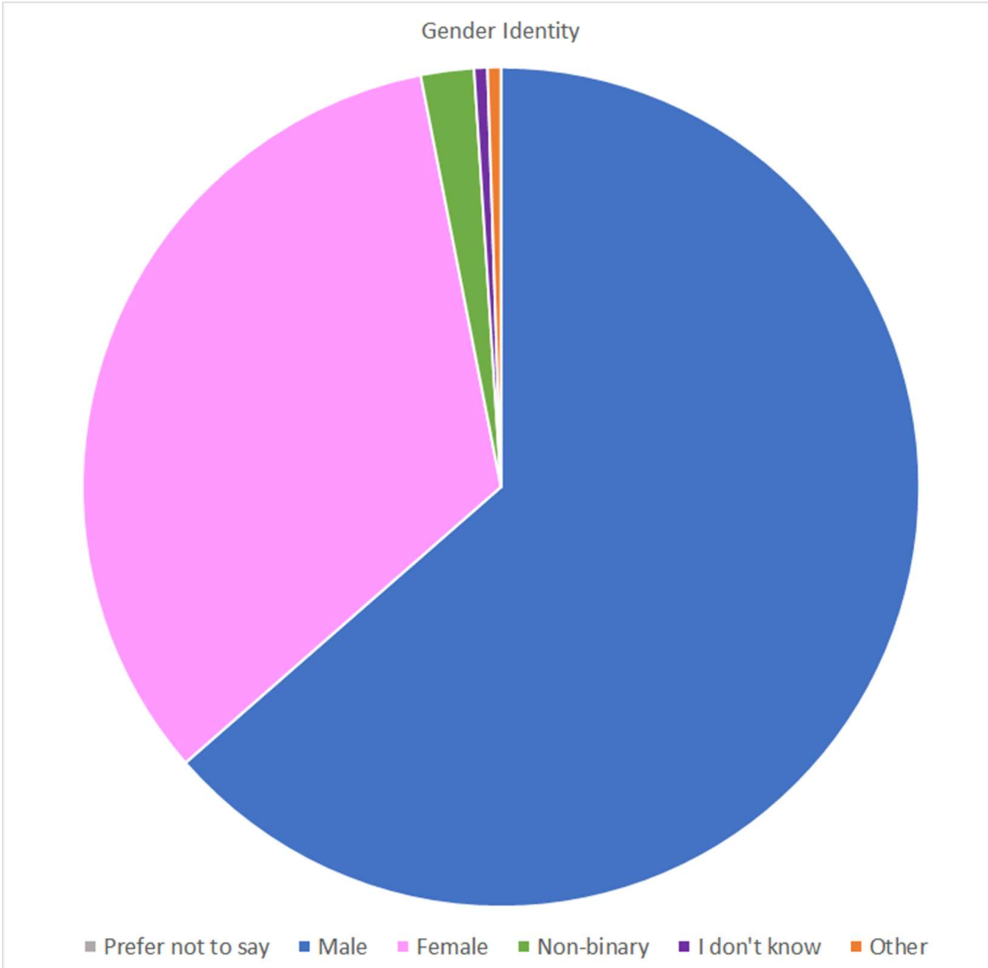


FIGURE 71. PARTICIPANTS GENDER IDENTITY PIE CHART

While it may not be feasible to represent all gender identities as equal proportions, the fact that the majority of participants identify as "Male" is still something to be aware of. One of the advantages of ABM is the representation of outliers or minorities in the simulation. Venkatesh et al. (2003) has previously reported how genders approached technology differently. This research does not expand on this nor does it make any claims related to gender other than there is a majority of participants that answered "Male" regarding their gender identity.

Age Range

The second demographic question asked the participants what their age was. The question was structured with the following responses: “Under 18”, “18 -24”, “25 -34”, “35 - 44”, “45 and above”, and of course, “Prefer not to say” and “I don’t know”. This demographic question chose to not use participants' date of birth to safeguard the participants anonymity. Participants who chose to answer “Under 18” were redirected to an end of survey page and their responses were not recorded. Again, any participants under 18 must have a guardian present.

TABLE 27. AGE RANGE RESPONSES

Answer	Number of responses	In percent
Prefer not to say	0	0.0%
Under 18	0	0.0%
18 - 24	92	47.2%
25 - 34	79	40.5%
35 - 44	17	8.7%
45 and above	6	3.1%
I don't know	1	0.5%

Thus, none of the participants were under 18. None of the participants answered “Prefer not to say”. 1 participant answered “I don’t know”. 6 participants answered “45 and above” which is 3.1% of the population of participants. 17 participants answered “35 - 44” which is 8.7% of the population. 79 participants answered “25 - 34” which 40.5% of the population. Finally, 92 participants answered “18-24” which is 47.2% of the population.

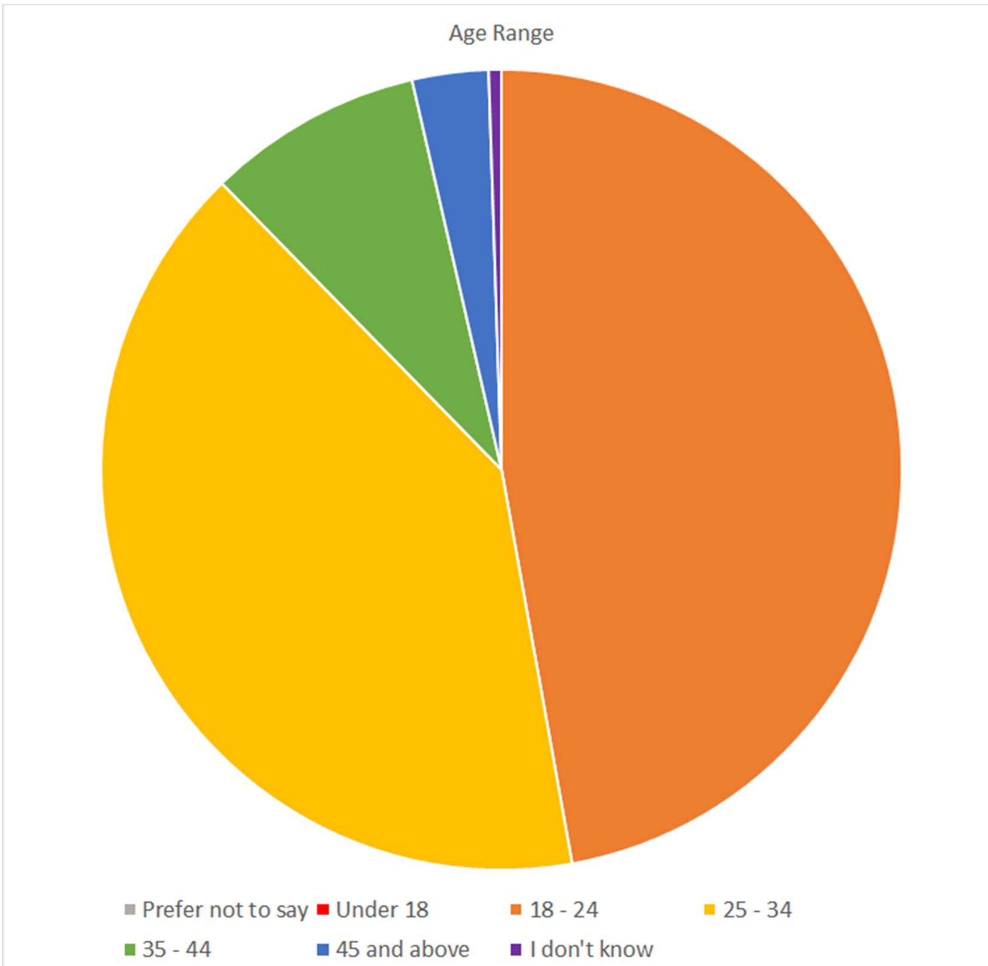


FIGURE 72. PARTICIPANTS AGE RANGE PIE CHART

There is a noticeable downwards trend as the age range becomes older. While the age range skew is present, it is not as drastic as the gender identity skew between “Male” and “Female”.

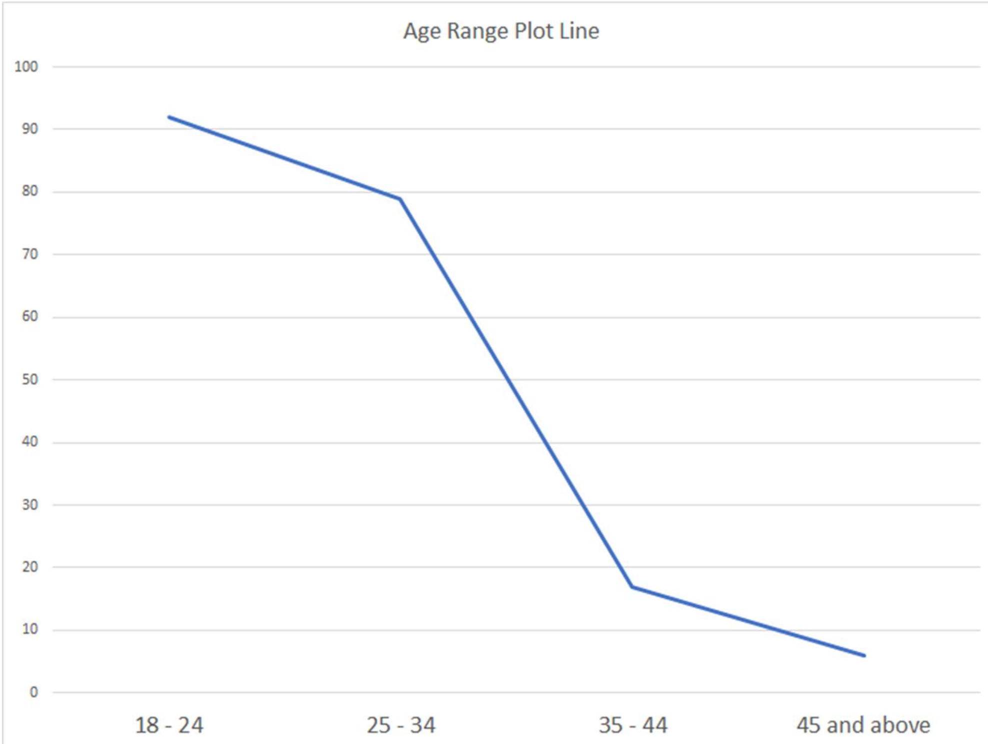


FIGURE 73. PARTICIPANTS AGE RANGE PIE CHART

Domestic or international student

The third demographic question asked participants if they were domestic or international students. The question was structured with the following responses: "Domestic", "International", "Other" which provided a textfield for participants to add a response, and not to forget, "Prefer not to say" and "I don't know".

Table 28. Domestic or International Responses

Answer	Number of responses	In percent
Prefer not to say	1	0.5%
Domestic	42	21.5%
International	147	75.4%
I don't know	1	0.5%
Other	4	2.1%

1 participant answered “Prefer not to say”. 1 participant chose “I don’t know”. 4 participants chose “Other” which 1 responded in the supplied textfield “Exchange” meaning that they were an exchange student, and another responded “Both - domestic enrolled but I haven’t lived here since I was 3”. The 2 remaining participants who answered “Other” left the supplied textfield blank. 42 participants answered “Domestic” which is 21.5% of the population. 147 participants answered “International” which is 75.4% which is very high.

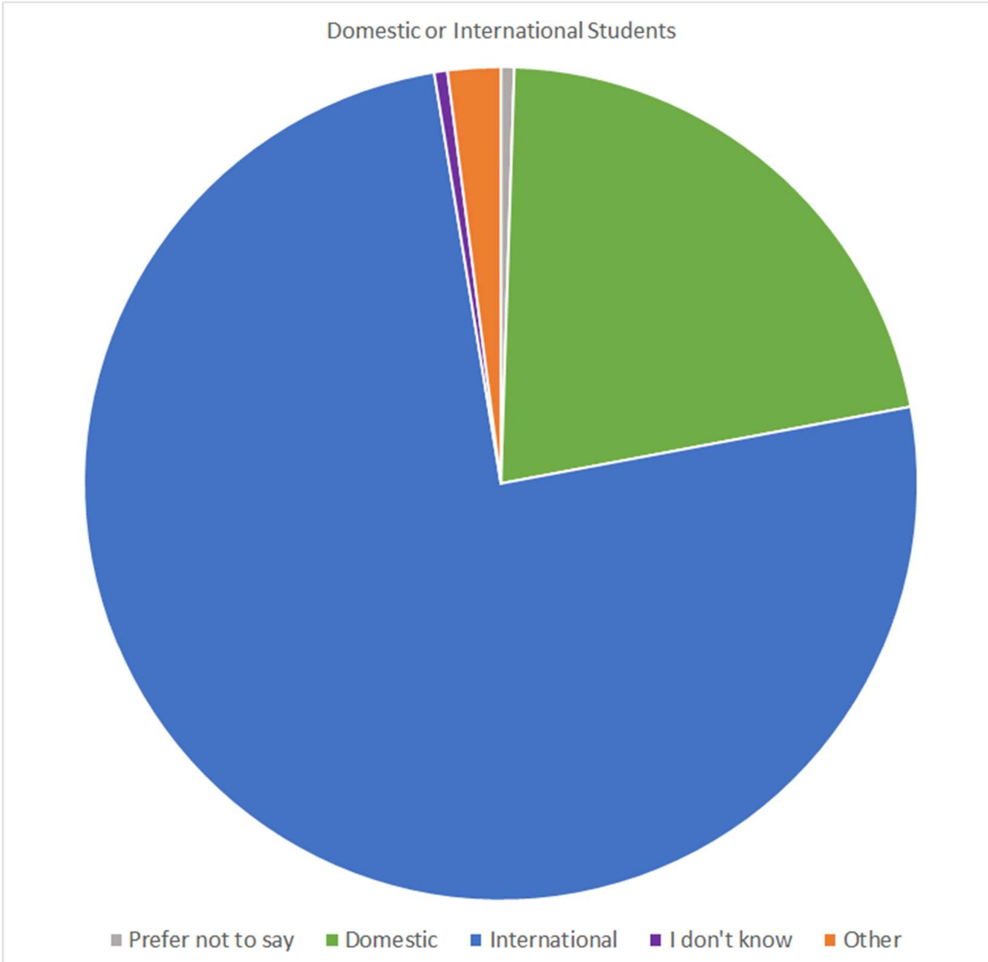


FIGURE 74. DOMESTIC OR INTERNATIONAL PIE CHART

Degree Undertaken

The final demographic question asked participants what they were currently studying. The question was structured with the following responses: "Undergraduate degree", "Postgraduate degree", "Research degree", "Other", and same as all the other demographic questions, "Prefer not to say" and "I don't know".

TABLE 29. DEGREE UNDERTAKEN RESPONSES

Answer	Number of responses	In percent
Prefer not to say	0	0.0%
I don't know	0	0.0%
Undergraduate degree	32	16.4%
Postgraduate degree	148	75.9%
Research degree	11	5.6%
Other	4	2.1%

None of the participants answered “Prefer not to say” nor “I don’t know”. Four participants answered “Other”. Among those 4, 1 replied in the supplied textfield “Master of AI”, another replied “Postdoc” which means postdoctoral, and the remaining 2 left the textfield blank. Eleven participants answered “Research degree” which is 5.6% of the population, while 32 participants answered “Undergraduate degree” which is 16.4%, 148 answered “Postgraduate degree” which is 75.9% of the population which is again a significant majority. Post graduate students are of higher education than the average person. Given that this thesis concerns knowledge transfer there may be a bias from this.

7. Submodels

There are no important sub-models for this experiment.

7.3.4 Implementation: Execution simulation

The simulation was implemented in AnyLogic 8 Personal Learning Edition 8.9.0 Build: 8.9.0.202404161236 x64, and executed using the data discussed in section 6. Input Data. The simulation was run for a duration of a lesson which is 3 hours or 180 minutes.

Simulation Results

Without Cognitive Empathy

The simulation shows that most students will converge towards a state of joy (positive active affective state). What is not visible from the screenshot is that during the simulation some students will fluctuate between different affective states. What is noticeable is that the students who fluctuate are always the same students.

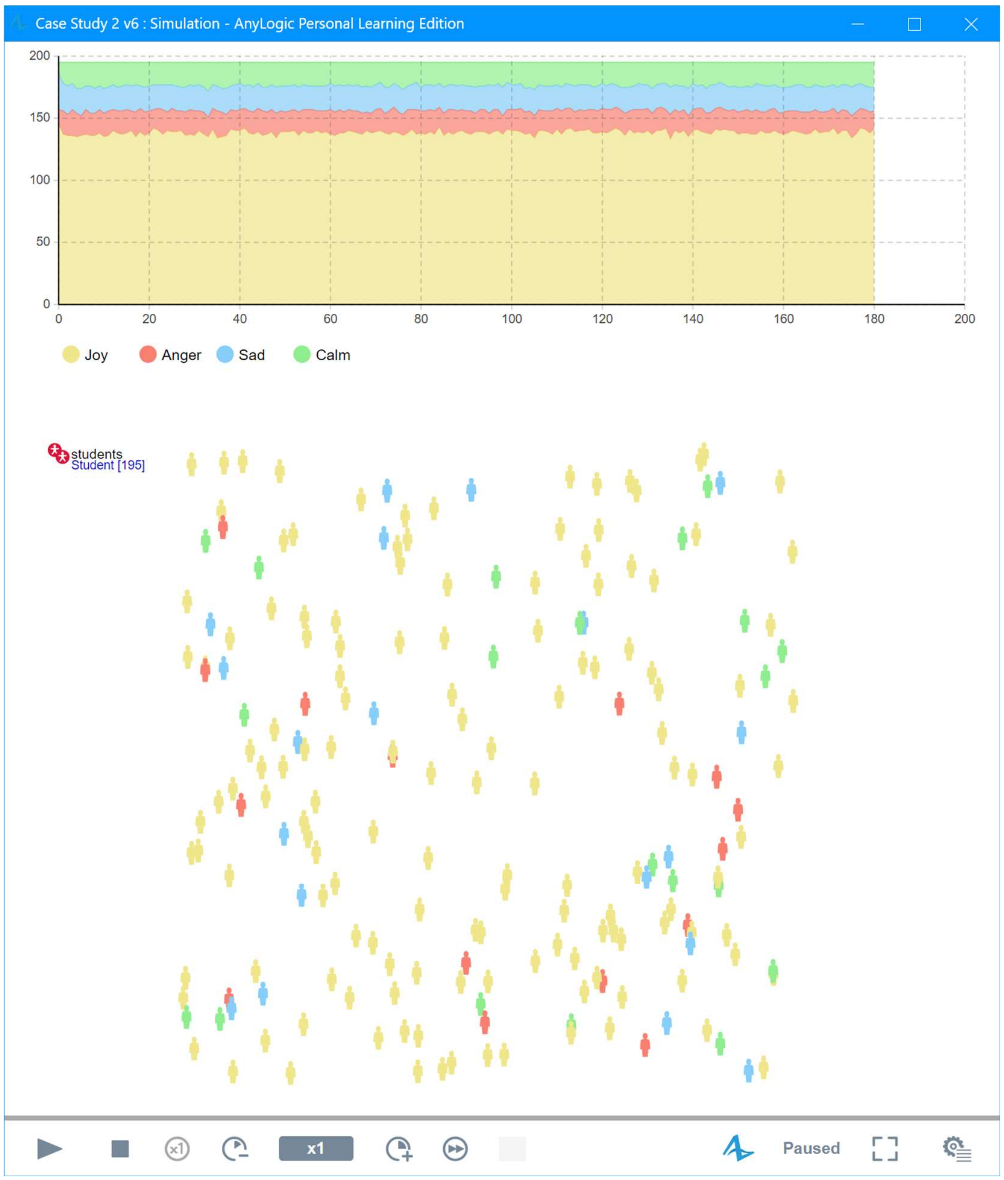


FIGURE 75. SIMULATION RUN FOR KNOWLEDGE TRANSFER AND AFFECTIVE STATES WITHOUT COGNITIVE EMPATHY.

At the end of the simulation, there were 35 agents that were in a state of hope, 41 in a state of enjoyment, 65 in pride, 2 in anxiety, 7 in anger (learning emotion), 6 in shame, 5 in hopelessness, 5 in boredom, 9 that were sad after the learning activity, 5 that were calm before, 9 that were calm during, and 6 in relief. By adding hope, enjoyment and pride into joy, there were 141 agents in joy. Adding anxiety, anger (learning emotion), and shame sums into 15 agents in anger (affective state). Hopelessness, boredom, and sad after sums into 19 agents that were sad. Finally, calm before, calm during, and relief sums into 20 agents that were calm.

TABLE 30. NUMBER OF AGENTS WITHOUT COGNITIVE EMPATHY BY LEARNING EMOTION.

Learning Emotion	Number of Agents without cognitive empathy
Hope	35
Enjoyment	41
Pride	65
Anxiety	2
Anger	7
Shame	6
Hopelessness	5
Boredom	5
Sad after	9
Calm before	5
Calm during	9
Relief	6

TABLE 31. NUMBER OF AGENTS WITHOUT COGNITIVE EMPATHY BY AFFECTIVE STATE.

Affective State	Number of Agents without cognitive empathy
Joy	141
Anger	15
Sad	19
Calm	20

With Cognitive Empathy

As one can observe, with the introduction of cognitive empathy, student affective states will fluctuate much greater. More importantly, the initial state of joy is no longer the predominant affective state. There seems to be an even distribution of calm, sad, anger, and joy.

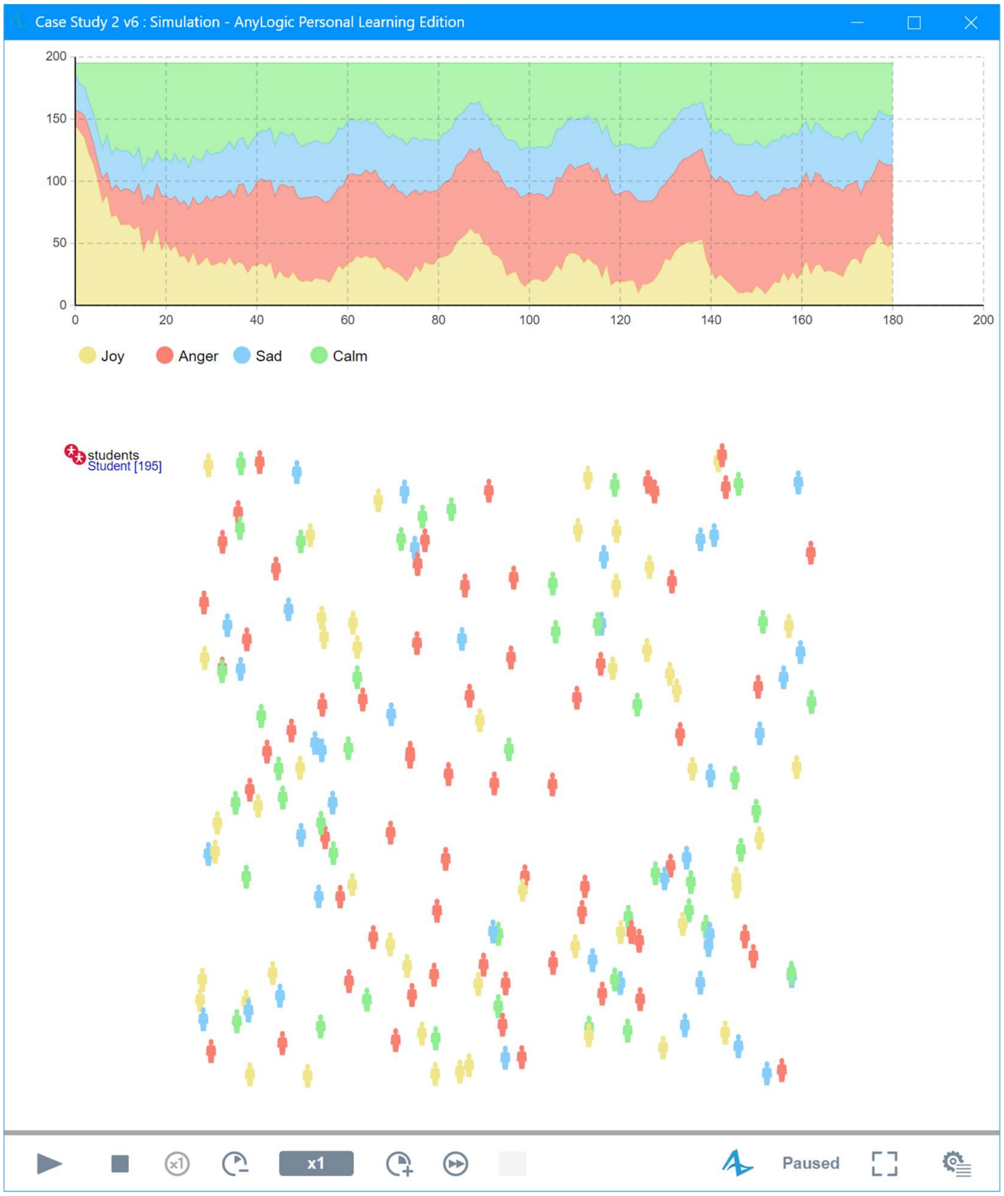


FIGURE 76. SIMULATION RUN FOR KNOWLEDGE TRANSFER AND AFFECTIVE STATES WITH COGNITIVE EMPATHY.

At the end of the simulation, there were 4 agents that were in a state of hope, 15 in a state of enjoyment, 31 in pride, 16 in anxiety, 21 in anger (learning emotion), 26 in shame, 7 in hopelessness, 13 in boredom, 19 that were sad after the learning activity, 20 that were calm before, 13 that were calm during, and 10 in relief. By adding hope, enjoyment and pride into joy, there were 50 agents in joy. Adding anxiety, anger (learning emotion), and shame sums into 63 agents in anger (affective state). Hopelessness, boredom, and sad after sums into 39 agents that were sad. Finally, calm before, calm during, and relief sums into 43 agents that were calm.

TABLE 32. NUMBER OF AGENTS WITH COGNITIVE EMPATHY BY LEARNING EMOTION.

Learning Emotion	Number of Agents with cognitive empathy
Hope	4
Enjoyment	15
Pride	31
Anxiety	16
Anger	21
Shame	26
Hopelessness	7
Boredom	13
Sad after	19
Calm before	20
Calm during	13
Relief	10

TABLE 33. NUMBER OF AGENTS WITH COGNITIVE EMPATHY BY AFFECTIVE STATE.

Affective State	Number of Agents with cognitive empathy
Joy	50
Anger	63
Sad	39
Calm	43

7.4 Discussion and Implications of the Results

7.4.1 Hypothesis Results

The following hypotheses have either been validated or not.

Hypothesis 2: Cognitive empathy affects an individual's affective states.

As seen in the simulation with cognitive empathy, there is a much greater difference in affective states of students and the collective. This hypothesis has been validated.

TABLE 34. NUMBER OF AGENTS WITH AND WITHOUT COGNITIVE EMPATHY BY AFFECTIVE STATE.

Affective State	Number of Agents without cognitive empathy	Number of Agents with cognitive empathy
Joy	141	50
Anger	15	63
Sad	19	39
Calm	20	43

7.4.2 Discussion of Results

Finally, **Hypothesis 2** has also been validated. It would be pointless to argue who came first, the chicken or the egg. The point here is that cognitive empathy intrinsic to humans including students affect the collective. Affective states of individuals affect the collective affective state and vice versa, the collective's affective state affects individuals. Beauvoir (1970, p. 87) points out that: "Humanity is not an animal species: it is a historical reality". The simulation of cognitive empathy gives merit to the idea that said historical reality was with affective states rather than clinically devoid of emotions. Individuals' negative or inactive states are not internal but the result of society. When treating mental illnesses, the social context should also be included.

7.4.3 Limitations

The representation of an agent's affective state based on their ACAP stage does not take into account the distinct factors of a context. While this simulation is general enough to provide some vision of an individual's learning emotion while they are learning, it cannot be a substitute for how a person feels in real life. Nevertheless, as the advantage of a simulation is to observe phenomena without affecting the real world, using ABM to simulate an individual's learning emotion provides an instrument to forecast individual emotions when they are learning. That is the collective represented in the simulation can only be virtual and cannot substitute how people will feel in real life. Again, the point of a simulation is to provide a best guess estimate which can and should be treated as a possibility and not a certainty.

The primary constraints that emerged from this experiment were related to the data acquisition during the simulation. The selection of items for data collection was contingent to the constructs employed in the ABM. Nevertheless, a subset of the data collection was excluded from the ABM. There are various possible reasons for this, including anticipating any potential deficiencies in the ABM, superfluous items in the questionnaire, ethical considerations, and so on. As previously stated, a few individuals expressed concerns about the length of the survey when it was issued. Although it was not possible to avoid this, the complaint is sound because the survey included 111 items (Likert type questionnaire). These flaws are not attributable to the ABM or the constructs it employed, but rather stem from procedural and administrative shortcomings. The preceding experiment highlighted the overlap between the ROADMAP analysis and the ODD design. Therefore, it is advisable to adopt a more systematic approach to model conceptualisation and data collecting in the simulation research design while creating an ABM. A simulation is limited to being only a virtual representation and cannot exceed this boundary. Although there are advantages and drawbacks, a simulation can only provide an approximation and cannot be considered more than an educated estimation. Although the statistical validity of a simulation can improve with an increase in data, there is a perpetual risk of requiring further data. The proverbial expression "how long is a piece of string?" serves to highlight the notion that quantity does not always equate to quality. This also fails to consider the personal autonomy and decision-making inside a certain situation or moment in reality. A simulation is inherently incapable and will never possess the ability to serve as a replacement for actual reality. Another constraint related to the data collecting is statistical validity. Although the critique regarding the lack of statistical validity in the data and calculations is legitimate, mathematicians and researchers will have no trouble finding solutions to address this issue. It is important to acknowledge that all statistical approaches have limitations. Therefore, dismissing any research only based on potential imperfections in the statistics is not a productive approach (Henseler et al., 2014). Although the fundamental notions of the model and their interactions are sound, any enhancements or adjustments to this ABM that enhance its validity are highly appreciated. Social media businesses, with their vast amount of data, resources, and lack of ethical rigour, should easily be able to enhance this ABM.

7.4.4 Further Recommendation and Conclusion

This could be for many different reasons for the changes in affective states in said students, however, this would require further investigation. This would also require the students who partook in the data collection and this is impossible as the data collection was anonymous and there is no feasible way to find out who participants are. It is also important to accept that individuals will during the course of their lifetime experience different emotions, and thus it is also reasonable to expect their affective state to fluctuate. Nevertheless, this ABM provides a solid stepping stone to investigate other phenomena that are dependent on emotions and knowledge transfer such as information disorders. The instrument provided by ABM is still valuable as it allows visibility into the future. It provides pedagogues the means to strategically plan and place specific individuals into certain groups to sway the general mood. ABM provides sociologists a tool to further investigate the diffusion of emotions in a collective or other social dynamics.

Chapter 8: Experiment 3, The Diffusion of Information Disorders and High Agreeableness

The following experiment expands from chapter 7 experiment 2 by adding information disorders. It does make some heavy assumptions; however, these assumptions have been reported as thoroughly as possible in the following chapter. It uses the same dataset as chapter 7. It answers this study's research questions 3.

8.1 Introduction

As demonstrated in the previous experiment, knowledge transfer isn't simply about information moving from one point to another. When it comes to people, knowledge transfer is also about emotions, obfuscation, truth, timing, and many other abstract elements (Davenport & Prusak, 1998, p. 5). Knowledge transfer isn't only a confrontation between truth versus obscurity. Lying, misunderstanding, gaslighting, silence, repression, suppression, confusion, delusion, and many more information disorders illustrate that knowledge can be made of various dimensions rather than a binary variable. For the first time in the history of humanity, the internet of things has connected everything and everyone. As the barrier to acquiring information fades, the flow of information should theoretically sprout knowledge. And yet, individuals have never been more divided because of information disorder (Kandel, 2020). In the complex digital world, understanding information disorders is very challenging (Kandel, 2020). As shown in the previous experiment, since ABM has the ability to model emotions of individuals as they learn it may be able to model the diffusion of information disorder which can in turn help understand them.

8.1.1 Research Aim

The aim of this experiment is to model the diffusion of information and its disorders.

8.1.2 Research Objectives

The objectives of this research are to:

- Propose a method to simulate the diffusion of information disorder.
- Observe how the intent to harm affects the diffusion of information.

8.1.3 Research Purpose

The purpose of this research is to offer an approach to simulate the spread of information disorder. There is currently no ABM that fulfils this purpose on the market.

8.1.4 Research Significance

This research would primarily be of benefits to students as by definition, students are people who are actively learning and people who are most affected by information disorders when they are actively learning or absorbing knowledge. It also experiments with the Agreeableness as a phenomenon rather than an individual personality trait. Another way to say this is, the experiment looks at how Agreeableness affects the diffusion of information disorder. This can be leveraged when forming classroom.

This research would be of benefit to:

- The social media industry with its large data could use this simulation to better predict and target. For example, using this method social media may be able to stop the spread of disinformation before it happens.
- Management could use this approach to model knowledge transfer and individual affective states in their organisation. This could allow forecasting, and thus better planning from managers, decision makers and anyone who has high amounts of power internally. Prusak (1997) citation of Hewlett-Packard's famous quote "If only HP knew what HP knows, we could be three times more productive!" shows how beneficial it would be for management to model diffusion of information disorder.
- The education industry would use this to model and observe how information disorder may affect their students.
- The IT and AI discipline would benefit from another use for ABM.
- Students, employees and other knowledge recipients would also benefit from this by the trickling effect from other stakeholders.
- Academia will of course benefit from further knowledge contribution.

8.2 Literature Review

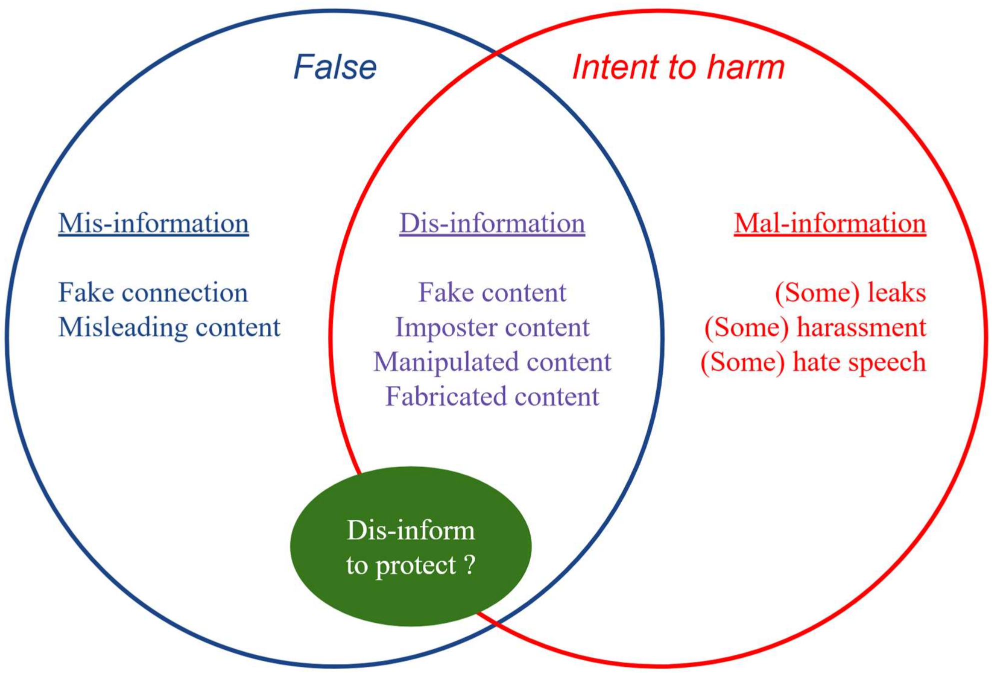
8.2.1 A Classification of Information: Information Disorders

Even though human beings have intelligence and wisdom and can distinguish right from wrong, they are victims knowingly or unknowingly of information disorders (Kandel, 2020). For further information about information disorder, see chapter 3. Information disorder is the sharing of false information whether or not there is an intent to harm (Kandel, 2020). Kandel (2020) classifies information disorders as:

Disinformation is information known to be false with the intent to cause harm which becomes misinformation once it has been shared (Kandel, 2020). There is an exception where disinformation can be created without an intent to harm. An individual can be prompted to create disinformation to protect themselves from a perceived potential threat. A stereotypical example would be a homosexual lying about their sexual orientation in a country where homosexuality is illegal. The intent to protect oneself and the intent to harm are not mutually exclusive. A person can spread disinformation to both protect themselves and harm others. Disinformation is colloquially known as lying.

Misinformation is information that is believed to be true even though it is false without the intent to cause harm (Kandel, 2020). The distinguishing feature that separates misinformation from disinformation is that the person who spreads misinformation believes the information to be true. Misinformation can present itself in a person in varying degrees from a simple misunderstanding or mistake to being delusional through confusion or gaslighting. For example, a person can be mistaken about the date an event took place to a classic example of someone believing the earth is flat. Szulanski (2000) points out that the more ingrained knowledge is, the more time and effort it will take to unlearn and relearn the new knowledge. It is possible that a person can be a victim of propaganda, gaslighting, or a collective lying which can root misinformation in said person. One of the barriers to ACAP is weak contract protection where the judiciary system does not provide an affordable and rapid dispute resolution (Cuervo-Cazurra & Rui, 2017; Zhao, 2006). A weak judicial system made of poor regulation and enforcement, means that contract compliance becomes uncertain (Cuervo-Cazurra & Rui, 2017; Djankov et al., 2002). Beauvoir (1970, p. 855) argues that truth is conductive of justice and without that enforcement of truth, people become both victims and abusers of the lie. The existence of misinformation is a symptom of a lack of justice.

Finally, **malinformation** is information which is shared with the intent to cause harm and known to be true (Kandel, 2020). Malinformation can sometimes be difficult to verify (Kandel, 2020). An example of malinformation is when someone shares private information that is used to tarnish a person or reputation (Kandel, 2020). It can also be information that is withheld until a moment that it will cause harm. Here, the malinformer will delay the release of said malinformation out of a sense of gratification.



Kandel (2020) Information Disorder and including the intention to protect

FIGURE 77. INFORMATION DISORDER WITH INTENTION TO PROTECT

With the internet of things, information disorders are more prevalent as the virtual environment spreads information (Kandel, 2020). The digital world is now ostracising people from one another instead of connecting them because of said information disorder (Kandel, 2020).

8.2.2 A Simplified View of Human Desires: The Colour Wheel of Love

Love as a word can have different types of meaning. A person can have a "loving" personality (Peabody & Goldberg, 1989) which can also be called agreeableness (Barrick & Mount, 1991). Love can also mean a person's desire or projected intention. Among the different types of human desires, there are three primary types of love: eros, ludus, storge (Lee, 1973).

Eros is where the individual chases one or more ideal images that may not be purely physical (Lee, 1973, p. 36). The individual may be willing to negotiate or compromise this ideal image as long as they do not lose anything from the trade-off (Lee, 1973, p. 36). Eros can be interpreted as an irrational egotism leading to disappointment, however, some still keep on hoping (Lee, 1973, p. 36). Eros describes well the specific individual passion or desire that one chases.

Ludus is the playing of games which when one player is bored the game finishes (Lee, 1973, p. 58). Multiple people can be players in this game but it is best played against a matching partner (Lee, 1973, p. 58). Competent ludic individuals will make the rules of the game explicit early (Lee, 1973, p. 58). Ludus describes the love of drama, or the desire of the game. Extreme versions of this can be sadism or evil where a player or many players have no respect for other individuals. Life sometimes can be a game in which the players are not awarded the rules.

Storge is a passion that is mediated by an activity or common interest which connects people (Lee, 1973, p. 77). Storge is more of a natural affection similar to love for a favourite sibling and not a passion (Lee, 1973, p. 77). It is without fever nor folly and is rarely urgent or hectic but is slow-burning love that can live long (Lee, 1973, p. 77). It can still have disagreement or conflict (Lee, 1973, p. 78). Storge meaning "divine" describes a desire that is shared by a group of individuals via a common platform.

Eros or passion, Ludus or playfulness, and Storge or fraternity describe the different types of desires or projection of an intent an individual can have. Each can be of varying degree but also be dependent on the context a person is in.

8.2.3 Agreeableness

As mentioned before, Agreeableness is the personality trait that is described as being courteous, flexible, trusting, good-natured, cooperative, forgiving, soft-hearted, and tolerant (Barrick & Mount, 1991). An individual with high agreeableness will tolerate a lot more, and will cease interaction with individuals who have breached their tolerance (Meier et al., 2006). Agreeableness as a personality trait may describe when an individual ceases connection when exposed to a degree of harm that they do not tolerate. While cognitive empathy describes the ceiling of an individual empathy, agreeableness describes when an individual ceases to interact with others.

8.2.4 Research Gap

There are currently no means to represent the diffusion of information disorder on the market. ABM has the ability to simulate decisions at the individual level.

8.2.5 Research Questions

RQ3: How does high agreeableness affect the diffusion of information disorder?

8.2.6 Scope

The scope of this experiment is to model agents information disorder (informing, misinforming, disinforming, malinforming) in an ABM and observe how Agreeableness affects diffusion of information disorder. This experiment 3 builds on top of experiment 2 as it uses an agents affective state to infer what information disorder an agent might execute. Once again, like in experiment 1 and 2, university or any students are the best population to collect data from.

8.2.7 Hypothesis Development

RQ3: How does high agreeableness affect the diffusion of information disorder?

Foucault (1977, pp. 253-254) describes three types of convicts:

- The vicious, stupid, or passive convicts who are led due to a lack of resistance to bad incitement.
- The inept or incapable convicts who are incapable of understanding social duties, which are individuals who have the intent to harm if one accepts that hurting another is a deficit in social duties.
- The convict who is above intelligence or dangerous who is to be isolated which would be the stoic or silent individual.

Each one of these convicts can be interpreted as different types of students. As there is currently no means to police information disorder (or they are very cost ineffective), the intent to harm underpinning malinformation and disinformation to harm would have an effect on the diffusion of information. However, individuals with high agreeableness would separate themselves from said social context. **Hypothesis 3a:** Agreeableness increases the spread of information disorders.

Hypothesis 3b: Agreeableness decreases the spread of information disorders.

8.3 Methodology: Agent Based Modelling

8.3.1 Analysis: Role Oriented Analysis and Design for Multi-Agent Programming (ROADMAP) method

The ROADMAP analysis method has been merged with the following ODD documentation as the latter is extensive enough.

8.3.2 Research Model: Overview, Design concept, and Detail (ODD)

1. Purpose

The purpose of this model is to model the diffusion of information disorders.

2. Entities, Variables, and Parameters

TABLE 35. LIST OF ENTITIES, VARIABLES AND PARAMETERS FROM PREVIOUS LITERATURE

Name	Description	Parameter, Variable, or Entity
Individuals		
Knowledge Source	Knowledge sources are an antecedent to knowledge acquisition (Zahra & George, 2002). They are sources of knowledge that recipients receive knowledge from.	Agent
Knowledge Recipient	Recipients of external knowledge (Szulanski, 1996).	Agent
Absorptive Capacity	Cohen and Levinthal (1990) first introduced the concept of ACAP as an organisation's capability to absorb knowledge. While ACAP is popular for organisations, research has used it at an individual level (Lowik et al., 2017)	Construct
Recognition	Scholars have often included value recognition with Acquisition (Todorova & Durisin, 2007), it is supported to be another capability along with the four capabilities of ACAP (Cuervo-Cazurra & Rui, 2017; Todorova & Durisin, 2007).	Parameter
Acquisition	Acquisition is the first capability where the object of knowledge is acquired (Zahra & George, 2002). Scholars	Parameter

	have often included value recognition with Acquisition (Todorova & Durisin, 2007). Some support that this is an independent capability from acquisition (Cuervo-Cazurra & Rui, 2017; Todorova & Durisin, 2007), while others argue the difference between recognising the need from value (Cuervo-Cazurra & Rui, 2017).	
Acquire	Acquire in this experiment represents the beginning of the knowledge absorption ACAP process. This is made of recognition and acquisition of ACAP.	Construct
Assimilation	Assimilation is defined as the capability to extract knowledge from an object (Zahra & George, 2002).	Parameter
Transformation	Transformation is the capability to reconfigure its knowledge process to connect it with prior knowledge (Zahra & George, 2002). It has been argued that Assimilation and Transformation are separate capabilities (Jansen et al., 2005; Todorova & Durisin, 2007).	Parameter
Assimilate	Assimilate in this experiment represents the climax of the knowledge absorption ACAP process. This is made of assimilation and transformation of ACAP.	Construct
Exploitation	In exploitation, knowledge is used and its value is returned (Zahra & George, 2002).	Parameter

Exploit	Exploit in this experiment represents the climax of the knowledge absorption ACAP process. This is made of exploitation of ACAP.	Construct
Affective State	Phye et al. (2007, p. 108) to define different states of affection, proposed a two-dimension approach with valence described as pleasantness and activation (Russell & Barrett, 1999; Tellegen & Watson, 1999).	Construct
Valence	Affective state dimension of valence pertains to pleasantness or hedonic tone (Feldman Barrett & Russell, 1998; Phye et al., 2007, p. 108; Russell & Barrett, 1999).	Variable
Motivation (Activation)	Affective state dimension of activation refers to energy, motivation (Feldman Barrett & Russell, 1998; Phye et al., 2007, p. 108; Russell & Barrett, 1999). This state of activation can be used to measure.	Variable
Collective Affective State	Collective affective state refers to the valence and activation that a collective has.	Construct
Collective Valence	This refers to the whole valence of a group.	Variable
Collective Motivation (Activation)	This refers to the whole activation or motivation of a group.	Variable
Empathy	Among the different definitions for Empathy, there is a consensus that it denotes the imaginative or intellectual	Parameter

	comprehension of another person's state of mind or condition (Hogan, 1969). Empathy has been considered as the cognitive ability and affective trait that is respectively the capacity to comprehend (Hogan, 1969) or to experience (Bryant, 1982) another's emotions (Jolliffe & Farrington, 2006; Marshall et al., 1995). It is considered a unique ability as it allows one to understand another person's position, as well as their feelings and their causes (Carré et al., 2013).	
Cognitive Empathy	Cognitive empathy is the capability to understand another's feeling (Carré et al., 2013).	Parameter
Love	The desire or projected intention of an individual.	Parameter
Eros	In Eros, the erotic individual pursues one or more ideal images where they are willing internally to compromise some traits for another as long as in their view the exchange is equal or of greater value (Lee, 1973, p. 36). The specific individual passion or desire that one chases.	Parameter
Ludus	The Ludic individual pursues to game love or in other words, they like to play games (Lee, 1973, p. 58). The desire is to play games.	Parameter

Storge	The storgic individual does not pursue any passion but storge is more of a natural affection without folly nor fever similar to love for a favourite sibling (Lee, 1973, p. 77). Empathy is shared via a desire mediated by a platform.	Parameter
Agreeableness	Personality is the characteristics of thinking, feeling, and behaving of an individual (Letzring & Adamcik, 2015). Being courteous, flexible, trusting, good-natured, cooperative, forgiving, soft-hearted, and tolerant are traits often associated with Agreeableness (Barrick & Mount, 1991).Also, people with high agreeableness tend to react less to aggression whereas people with low agreeableness when exposed to antisocial semantics will become more prosocial (Letzring & Adamcik, 2015; Meier et al., 2006).	Parameter
Protection	Protection Motivation Theory conceptualises individuals' motivation to participate in protective behaviours in the presence of a threat (Kim et al., 2022).	Parameter
Delayed Gratification	Delaying gratification refers to the tendency to forego strong immediate satisfaction for the sake of salient long-term rewards (Hoerger et al., 2011).	Parameter
Spatial unit		

Time	The more ingrained the experience is, the more time will be needed to unlearn and relearn new knowledge (Szulanski, 2000).	Parameter

3. Process Overview and Scheduling

As per the previous experiments, the ABM will be set to a minute's time scale as a lesson at UTS is 180 minutes. The same business process diagram used in the previous experiment is used here to illustrate the process and the schedule as well as other parameters that affect the learning.

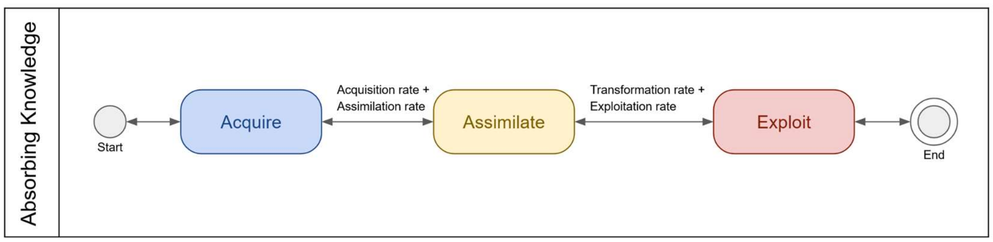


FIGURE 78. LEVEL 1 BUSINESS PROCESS DIAGRAM FOR ACAP

The ACAP model is simplified to only 3 stages of acquisition as the beginning stage, assimilation as the middle or climax of the process, and exploitation as the concluding stage. As each agent will go through the ACAP process at different rates, the model is asynchronous.

4. Design Concepts

Basic Principles

ACAP

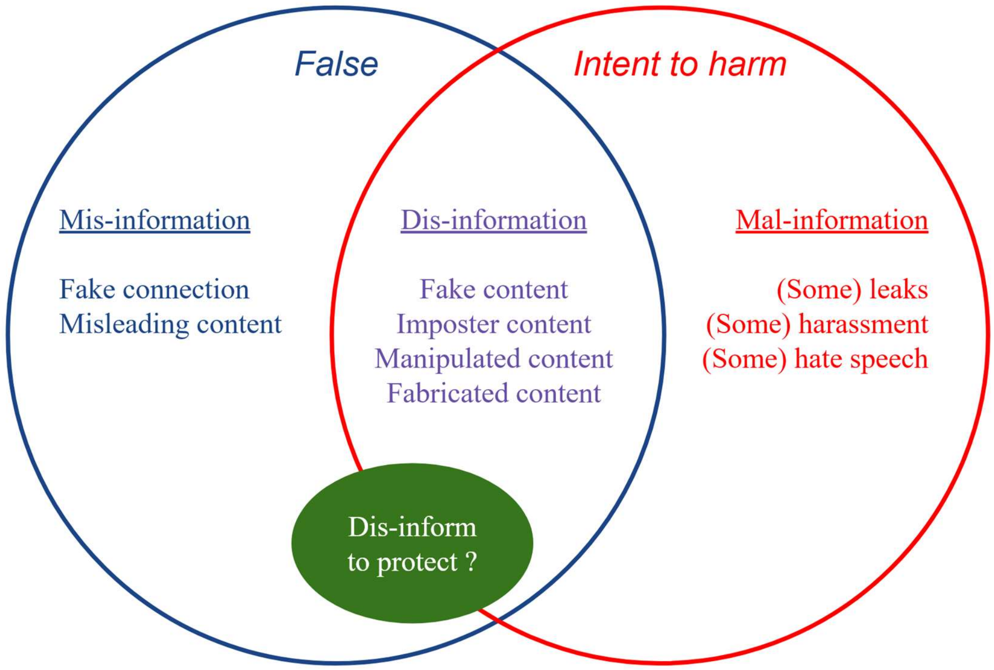
ACAP has not been expanded upon since the previous experiment. Here, it is made of acquired which represents the capability to acquire knowledge, assimilated which represents both assimilation and transformation of knowledge, and exploited which is the exploitation of knowledge. These capabilities are used to illustrate respectively the beginning (acquire (*acq*)), the climax (assimilate (*ass*)), and the conclusion (exploit (*exp*)) of the knowledge absorption or learning process.

Affective States

Affective states have not been expanded upon since the previous experiment. Here, affective states are decoupled into the dimension of activation or otherwise known as motivation (m), and valence (v). A snapshot of affective states has been taken at three stages of learning which is at the beginning (acquire), the climax (assimilate), and the conclusion (exploit).

Information Disorder

Information disorder was included in the previous experiment. It is now included here. Information disorder is made of misinformation, disinformation, and malinformation. Disinformation and malinformation are underpinned by an intent to harm. The previous experiment allowed one to model a knowledge recipient's state of anger during learning. Anger can be assumed as an intent to harm. This is a big assumption that is needed to model this experiment.



Kandel (2020) Information Disorder and including the intention to protect

FIGURE 79. INFORMATION DISORDER WITH INTENTION TO PROTECT

We have argued previously that disinformation can be underpinned by a motivation to protect and that this motivation is not mutually exclusive to the intent to harm. The motivation to protect can be measured using an instrument modified from Kim et al. (2022). Disinformation and malinformation although both underpinned by an intent to harm differ in their execution. Disinformation is known by its author to be not true or in other words a lie. Malinformation is truth being withheld until it can be used to cause harm. Another assumption made by this experiment is that the delay in gratification underpins the knowledge sources application of intent to harm using information. There may be other reasons for the causes that distinguish disinformation and malinformation. The field of psychoanalysis can sort this out. Currently, this experiment uses Hoerger et al. (2011) to measure an individual's determination to delay gratification. To the knowledge recipient, from their subjective point of view, information and misinformation is the same. The knowledge that is required to distinguish information from misinformation is not yet known to them.

Empathy

Another important element to the diffusion of information disorder is empathy. While a person can feel different emotions during the course of their life, cognitive empathy is a ceiling to the amount of empathy a person can have within any moment. Cognitive empathy is measured by Carré et al. (2013) BES-A scale. Here, cognitive empathy is used to separate Eros from Ludus or Storge as these require a certain amount of emotional reception or cognitive empathy. Agreeableness is a personality trait that leads to a behaviour where an individual when hurt or angry ceases interaction with another individual or group altogether. This is measured by Goldberg (1992). Here, agreeableness is used to separate Ludus from Storge. While Storge and Ludus may both have cognitive empathy, these differ in their empathetic alignment. Ludus may enjoy negative valence in another individual while Storge will align their empathy with other individuals. This description fits the personality trait agreeableness where an individual will "agree" with another up to a certain threshold. The combination of these parameters can model a behaviour useful in the simulation of the diffusion of information disorder.

Emergence

As this is not applicable to this study, emergence will not be expanded upon.

Adaptation

Absorptive CAPacity (ACAP)

Acquisition rate, Assimilation Rate, Transformation Rate, and Exploitation Rate is calculated as the average of the answers for each one of the ACAP capabilities for each record. This is the same as the previous experiment.

Affective States

As stated before, Pekrun et al. (2011) offers the means to measure affective states before, during, and after a learning activity. This allows the measurement of the changes in valence (v) and in motivation (m) across time. This is the same as the previous experiment.

Information Disorder

While information disorder is classified as the sharing of false information (Kandel, 2020), information disorder contains misinformation, disinformation, malinformation. Information is the spread of true information. Information and misinformation differ by the quality that the information is objectively true or false. From an agent's point of view, subjectivity and objectivity are the same. Perception is reality. Thus here, information and misinformation are therefore represented as the same. As stated, before cognitive empathy is the ceiling for which a person can feel empathy (Carré et al., 2013). If the individual doesn't care about the information they receive, they would simply pass it on without any reasoning or rationale towards information disorder. Here, cognitive empathy acts as a parameter that differentiates between inform/misinform (no empathy) and any further logic. During the learning, if the motivation (activation) is high and the valence is negative then the affective state is anger (Pekrun et al., 2011). This experiment assumes that anger is the antecedent to intent to harm. Anger during the learning activity acts as the variable that differentiate malinformation and disinformation (harm) to cause harm from disinformation (protect) to protect and inform/misinform (trust). If the agent is not angry, they are still capable of lying to protect themselves. Whether the perception of a threat is true or false is irrelevant as to the agent the threat appears real. The will to protect is assumed here as a parameter that differentiates between disinform (protect) and inform/misinform (no protection) to carry on the information. If the agent is angry, agreeableness would determine if the agent participates in the spread of information disorder or not. With high agreeableness, individuals will tolerate a lot more and cease interactions (Meier et al., 2006). Agreeableness becomes the parameter that differentiates between remaining silent and any participation into the spread of information disorder. If the agent is not agreeable, this experiment assumes that the agent's ability to delay gratification. This is a big assumption as the context, the individual experience, their intellect, their prior knowledge and other critical factors would determine whether they choose malinformation or disinformation (harm). This experiment will leave this to the experts such as psychoanalysts professionals, sociologists, and future research to sort this out. This experiment explicitly states that long term gratification is the parameter that differentiates between malinformation and disinformation (harm). All these different variables used to represent different decisions made at different points in time are also in its whole an assumption. Again, the experts such as psychoanalysts professionals, sociologists, and future research should sort the rationales that differentiate the different types of primary love of eros, ludus, and storge and how these affect the spread of information disorder.

Spillover

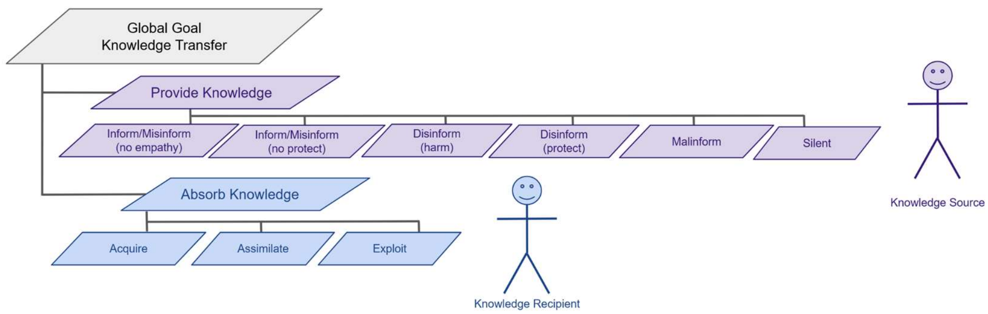
This experiment is able to expand the spillover. As per the previous experiment, the number of social connections (*e*) can be to a simple averaging of the LSNS response for an agent. Cognitive empathy is also included in this experiment as it is expected that a student's affective state affects each other. On top of this, this experiment can make use of other parameters or variables for its spillover. The new parameter added is agreeableness. If a student or agent has high agreeableness, they would isolate themselves from their group. In this case, any spillover would be of 0 as they would not interact with anyone.

Objectives

Goal Model

The goal model for this experiment is for knowledge transfer. Here, the agents for this model are the knowledge source and knowledge recipient even though in the model these will be the same as the knowledge recipient becomes a knowledge source. The goal of the knowledge recipient has not changed from the previous experiment. Its goal is to absorb knowledge which has been decomposed as acquire, assimilate, and exploit.

The goal of the knowledge source is to provide information. Inform and misinform are both believed to be true by an agent, these goals are the same. They have, however, been decoupled into one where there is no empathy and another where the agent carries on the information as they do not perceive a need to protect themselves. Disinform is another sub goal which is decomposed by its intent one for harm disinform (harm), and one for protection disinform (protect). While intent to harm and the intent to protect are not mutually exclusive, in the realisation of the spread of information disorder, the intent to cause harm does supersede the intent to protect. The other sub goals of the knowledge source are malinform, and silent. There is an important point to be made about the knowledge source and knowledge recipient. Once a knowledge recipient has absorbed knowledge, they become themselves a knowledge source. Therefore, while this experiment in its analysis and design distinguishes knowledge source and knowledge recipient, in the implementation, these agents are the agent.



This diagram is a goal model for ACAP for knowledge transfer with information disorder.

FIGURE 80. GOAL MODEL FOR ACAP IN KNOWLEDGE TRANSFER

Role Model

Here are the role models for the knowledge recipient and the knowledge source.

TABLE 36. ROLE MODEL FOR A KNOWLEDGE RECIPIENT IN THE DIFFUSION OF INFORMATION DISORDER

Role ID	KR1
Name	Knowledge Recipient
Description	Absorb knowledge from a Knowledge Source.
Responsibilities	Absorptive Capacity: A knowledge recipient's sole responsibility is to absorb new knowledge. This can be represented by the absorptive capacity framework which provides a measurement for the rate of learning.
Metrics	Absorptive Capacity: is made of acquisition, assimilation, transformation, and exploitation. Lowik et al. (2017) provides a survey to measure a person's absorptive capacity. Affective state: Valence and Motivation (Activation). This is measured using the learning emotions questionnaire from Pekrun et al. (2011). Cognitive Empathy: the ceiling that an individual has for feeling another's emotions. Carré et al. (2013) provides the BES-A scale that measures Cognitive Empathy.

	Agreeableness: personality trait which describes an individual who tolerates a lot but once their limit has been reached ceases interaction. Agreeableness can be measured with the Big 5 personality trait from Goldberg (1992). Social network: the quantity of social connection a person can have. James et al. (2006) provide the Lubben Social Network Scale that provides a quick snapshot of a person's social network.

This table is the role model for knowledge recipients in knowledge transfer with information disorder.

TABLE 37. ROLE MODEL FOR A KNOWLEDGE SOURCE IN THE DIFFUSION OF INFORMATION DISORDER

Role ID	KS1
Name	Knowledge Source
Description	Provide Knowledge to Knowledge Recipients.
Responsibilities	A knowledge source responsibility is to provide knowledge to a knowledge recipient. A knowledge source can either inform, misinform, disinform, malinform, or remain silent. Information is a message whose content is justified to be true and believed to be true by the knowledge source. Misinformation is a message whose content is not justified to be true but is believed to be true by the knowledge source. Misinformation is not intentional.

	Disinformation is a message whose content is not justified to be true and believed to be not true by the knowledge source. The difference between disinformation and misinformation lies in the intent of the knowledge source to deceive. Malinformation is a message which is true. Malinformation differs from information in the source's intent to harm. The precondition for the intention to harm is that the knowledge source has empathy but they have no agreeableness (Love) for the knowledge recipient. Silent is a situation when the knowledge source is not sharing information.
Metrics	Affective state: Valence and Motivation (Activation). This is measured using the learning emotions questionnaire from Pekrun et al. (2011). Intent to harm: Anger is an emotion of learning and can be an indicator for intent to harm. Anger is a learning emotion as negative motivation during the learning activity (Pekrun et al., 2011) . Intent to protection: An individual can lie to protect themselves. Kim et al. (2022) provides a survey to measure a person's motivation to protect. Delayed gratification: an individual can withhold truth until it can cause harm later. Hoerger et al. (2011) provides a survey to measure a person determination to delay gratification

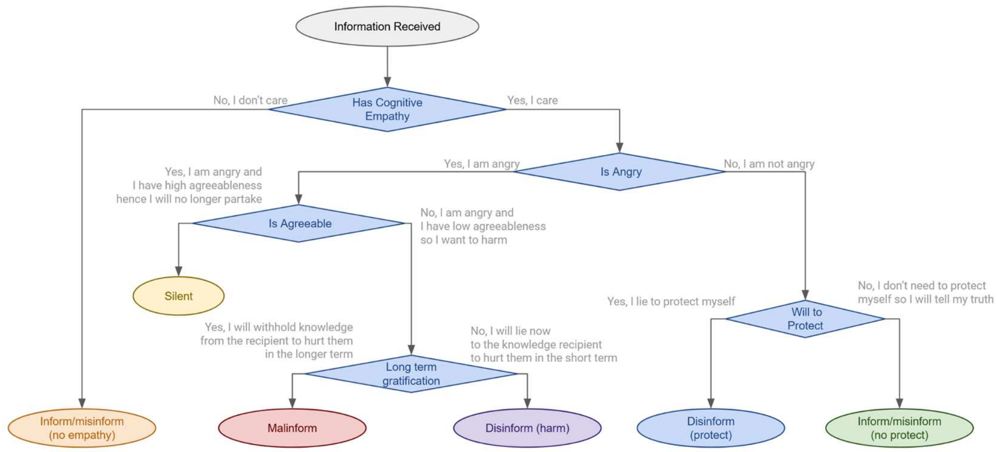
This table is the role model for knowledge source in knowledge transfer with information disorder.

Measurements

Lowik et al. (2017) provides a survey to measure an individual’s ACAP. Learning Emotions can be measured using Pekrun et al. (2011). Carré et al. (2013) provides the BES-A scale that measures an individual’s cognitive empathy. Goldberg (1992) provides the means to measure agreeableness from the big 5 personality traits. Among the 10 items that measure agreeableness, the items 7 to 10 are reversed. Protection can be measured using the PMT from Kim et al. (2022). Hoerger et al. (2011) provides a survey to measure a person's determination to delay gratification with the DGI scale. Items 1, 5, 6, 7, and 9 are reversed. The social network for an agent is measured LSNS originating from James et al. (2006).

Representations

In order to model an agent's decision to spread information disorder, a flow chart was used as it explicitly models the branches as decisions and the sequence of these branches. Recapping the information from adaptation, this section uses the measurements to differentiate an agent's action. Cognitive empathy is the parameter that is used as the first branch that separates inform/misinform (no empathy) with any further logic. Learning emotions are used to determine if the agent is angry during the learning activity which differentiates malinformation and disinformation (harm) to cause harm from disinformation (protect) to protect and inform/misinform (trust). Even if the agent is not angry, protection will differentiate between disinform (protect) and inform/misinform (no protection). If the agent is angry, low agreeableness assumes the agent would participate in the spread of information disorder. If they do participate, then the agent’s will to delay gratification is assumed to differentiate malinformation from disinformation (harm). The flowchart requires many assumptions to model the differentiation between the different types of information disorder. Another point to be made about this experiment is that once a knowledge recipient has absorbed knowledge, they become themselves knowledge sources.



Flowchart of an agent decision to spread information disorder with the intention to protect

FIGURE 81. INFORMATION DISORDER WITH INTENTION TO PROTECT FLOWCHART

Calculations

Similar to the previous experiment, before any further calculations, the LSNS responses have been translated to their correct values. Responses that are to be reversed from agreeableness and delayed gratification were calculated by taking the original value from the Likert type scale (values ranging from 1-5) and subtracting them from 6 (1 becomes 5, 2 becomes 4… 5 becomes 1). Any further calculations have been described in the Adaptation section. The calculation for the change values for affective state during ACAP is the same as for per the previous experiment. The dataset used in this experiment is from a different data collection which has been described in detail in the Data Collection section. Any further calculations have been described in other sections.

Learning

As this is not applicable to this study, learning will not be expanded upon.

Prediction

As this is not applicable to this study, prediction will not be expanded upon.

Sensing

As this is not applicable to this study, Sensing will not be expanded upon.

Interaction

Activities

This case uses the same activities for the knowledge recipient as the previous studies.

TABLE 38. AGENT MODEL

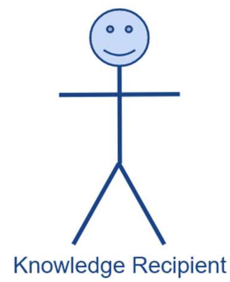
Agent ID	KR	Agent Name	Knowledge Recipient

Activity Name	Acquire
Roles Played	Knowledge Recipient
Functionality	Acquire knowledge
Precondition	Start Or Received knowledge spillover
Postcondition	Knowledge will be assimilated

Activity Name	Assimilate
Roles Played	Knowledge Recipient
Functionality	Assimilate knowledge
Precondition	Knowledge must be acquired
Postcondition	Knowledge will be transformed

Activity Name	Exploit
Roles Played	Knowledge Recipient
Functionality	Exploit knowledge
Precondition	Knowledge must be transformed
Postcondition	End Or Spillover to another knowledge recipient

Environmental Considerations



This diagram illustrates the different activities a knowledge recipient can perform.

FIGURE 82. ACTIVITY MODEL FOR KNOWLEDGE RECIPIENT IN A UNIVERSITY COURSE

The knowledge sources activities are what is added in this experiment.

Agent ID	KS	Agent Name	Knowledge Source

Activity Name	Disinform (protect)
Roles Played	Knowledge Source
Functionality	Lies (distorts information) to protect themselves.
Precondition	The information is originally true.
Postcondition	The information is false.

Activity Name	Disinform (harm)
Roles Played	Knowledge Source
Functionality	Lies (distorts information) to cause harm to another.
Precondition	The information is true.
Postcondition	The information is false. The knowledge recipient has been harmed.

Activity Name	Inform/misinform (no protect)
Roles Played	Knowledge Source
Functionality	Transmit knowledge to knowledge recipients.
Precondition	The knowledge source trusts the information.
Postcondition	The knowledge recipient has received the information.

Activity Name	Inform/misinform (no empathy)
Roles Played	Knowledge Source
Functionality	Transmit knowledge to knowledge recipients.
Precondition	The knowledge source trusts the information.
Postcondition	The knowledge recipient has received the information.

Activity Name	Malinform
Roles Played	knowledge Source
Functionality	Tell the truth to hurt the knowledge recipients.
Precondition	The information is true.
Postcondition	The knowledge recipient has been hurt.

Activity Name	Silent
Roles Played	Knowledge Source
Functionality	Ignore knowledge transfer.
Precondition	The knowledge source ignores the transfer and remains silent.
Postcondition	The knowledge source does not assimilate the information.

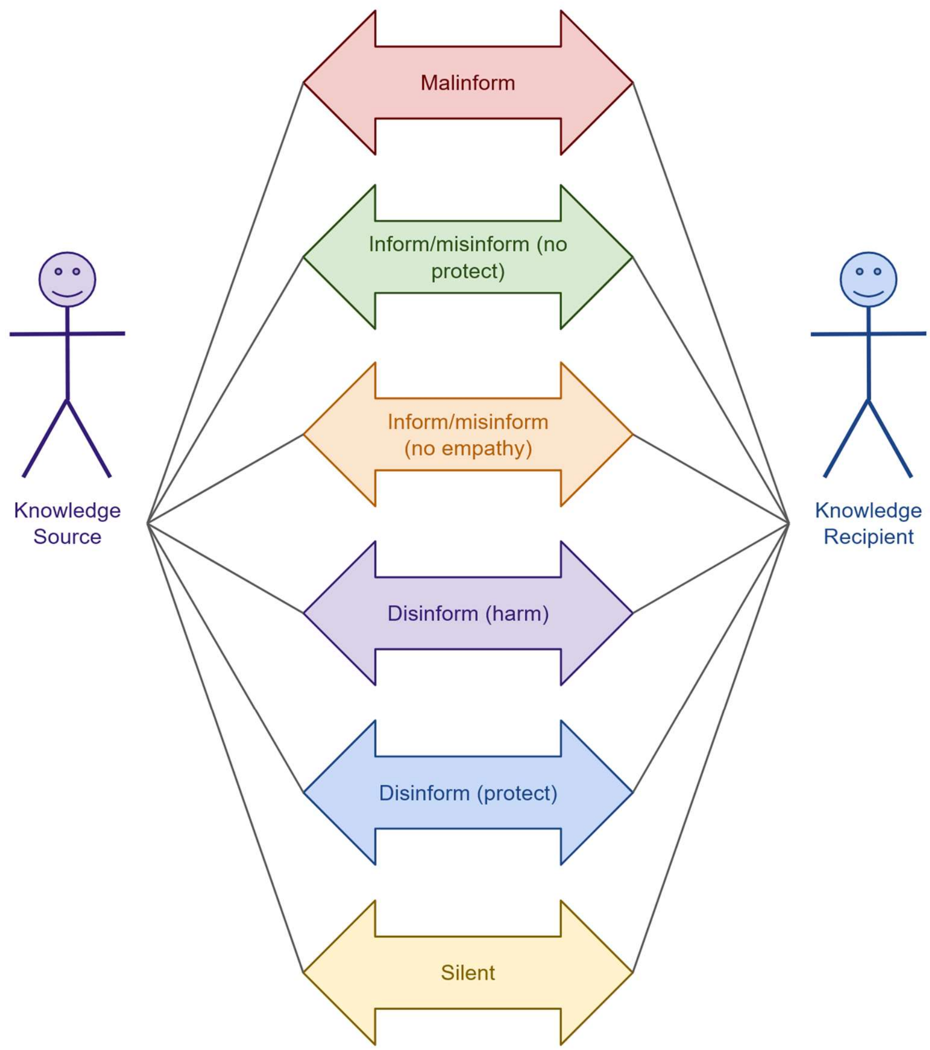
Environmental Considerations

This diagram illustrates the different activities a knowledge source can perform.

FIGURE 83. ACTIVITY MODEL FOR KNOWLEDGE SOURCE IN A UNIVERSITY COURSE

Interactions

This experiment updates the interaction model with the knowledge source. Again, once the knowledge recipient has absorbed the knowledge from the knowledge source, they become themselves a knowledge source. This interaction model therefore does not have knowledge recipient interacting with knowledge recipient as the knowledge would transfer in one direction.



This diagram illustrates the different interactions as activities a knowledge recipient and source can perform with another.

FIGURE 84. INTERACTION MODEL FOR KNOWLEDGE SOURCE WITH RECIPIENT IN A UNIVERSITY COURSE

Stochasticity

As this is not applicable to this study, Stochasticity will not be expanded upon.

Collectives

Collectives have not been expanded since the previous chapter 7. Cognitive empathy is still used as a means to simulate the diffusion of affective states.

Observation

Running the simulation will allow the observation of the fluctuation of Affective States over time giving an overall view of context and perhaps more importantly which Affective State dominates.

5. Initialization

Setting up the simulation

For this experiment, the simulation was designed and executed using AnyLogic 8 Personal Learning Edition 8.9.0 (Build: 8.9.0.202404161236 x64). The simulation was set to minutes.

Main model

In the “Main - agent type” window, within its “Properties” tab, under the “Space and network” section, the “Layout type:” dropdown box was set to “Random”. This will display agents at one random location in the simulation.

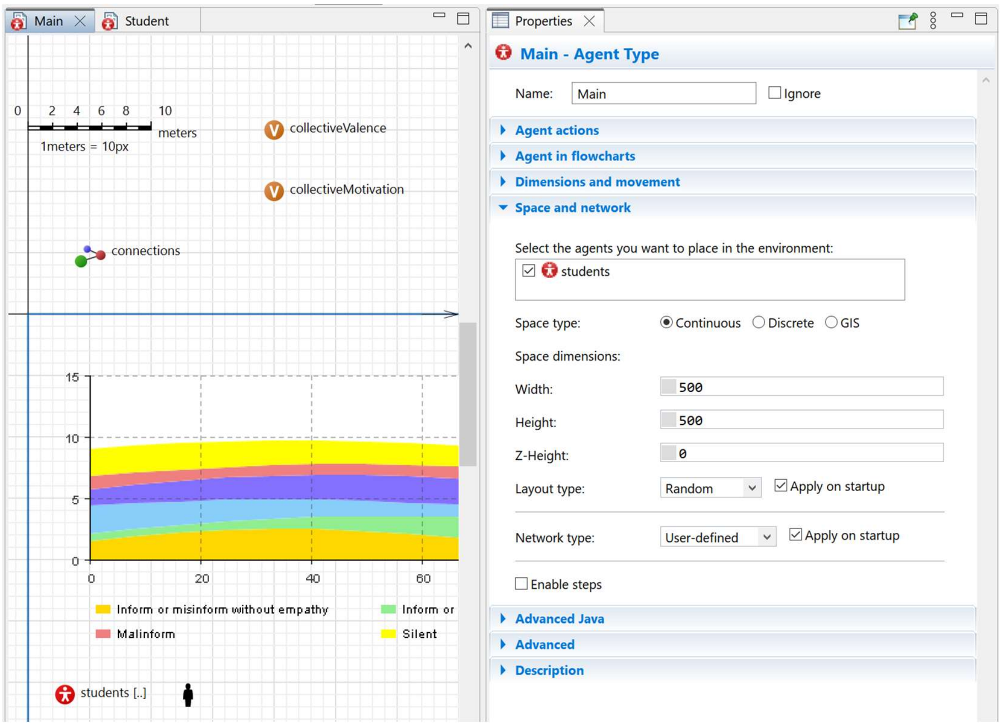


FIGURE 85. IN "MAIN - AGENT TYPE" WINDOW, "PROPERTIES" TAB, "SPACE AND NETWORK" SECTION, "LAYOUT TYPE:" SET TO "RANDOM"

Selecting the "Lesson_presentation - Agent Presentation" (by clicking the person icon), within its "properties" tab, under the "Advanced" section, the "Draw agent with offset to this position" checkbox was checked". This will display each agent at a distinct location in the simulation.

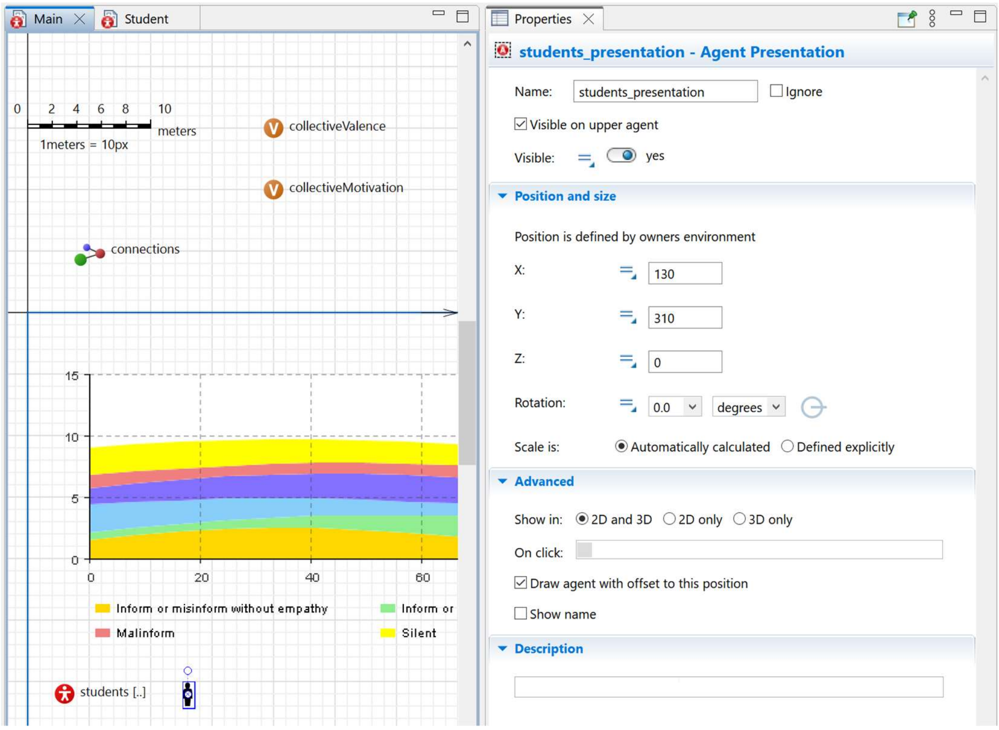
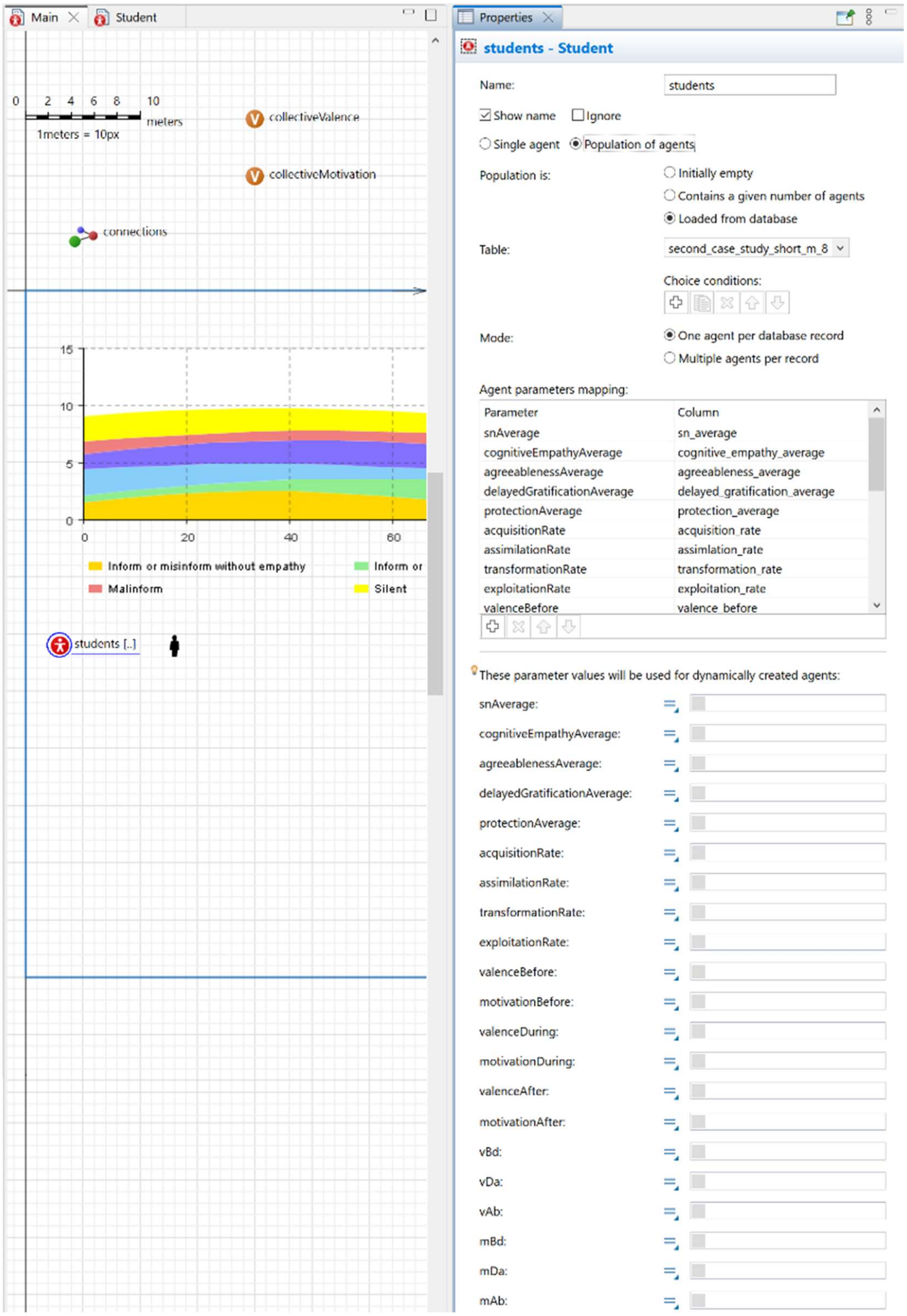


FIGURE 86. IN "MAIN - AGENT TYPE" WINDOW, SELECTING "STUDENTS_PRESENTATION - AGENT PRESENTATION" ICON, "PROPERTIES" TAB, "ADVANCE" SECTION, "DRAW AGENT WITH OFFSET TO THIS POSITION" CHECKED

Selecting the "Student" in the "Main - agent type" window, within its "properties" tab, the "Population is:" radio button list is selected to "Loaded from database" and its dropdown box is set to the data loaded into the database (See "6. Input Data" section for further information). This will load data from a database into the simulation. The "Mode" radio button list is selected to "One agent per database record". This will create an agent for each record in the database. In the "Agent parameter mapping:" table, each record maps a "Parameter" from the "Student - agent type" to a "Column" from the database. Here, the parameter rates are mapped to their corresponding database rate. Statistics count the students for each different ACAP state. Thus, in "Statistics" section, there is a statistic for each information disorder state whose "Name:" textfield is set to the name of the information disorder, the "Type:" radio button is set to "count", and the "Condition:" textfield is set to the instruction "item.inState (Student." name of the information disorder state ")". These statistics can then be used for graphs and other visualisations.


Main
Student
1meters = 10px
meters
collectiveValence
collectiveMotivation
connections
Inform or misinform without empathy
Malinform
Inform or
Silent
students [..]
Properties
students - Student
Name:
students
Show name
Ignore
Single agent
Population of agents
Population is:
Initially empty
Contains a given number of agents
Loaded from database
Table:
second_case_study_short_m_8
Choice conditions:
Mode:
One agent per database record
Multiple agents per record
Agent parameters mapping:
Parameter
Column
snAverage
sn_average
cognitiveEmpathyAverage
cognitive_empathy_average
agreeablenessAverage
agreeableness_average
delayedGratificationAverage
delayed_gratification_average
protectionAverage
protection_average
acquisitionRate
acquisition_rate
assimilationRate
assimlation_rate
transformationRate
transformation_rate
exploitationRate
exploitation_rate
valenceBefore
valence_before
These parameter values will be used for dynamically created agents:
snAverage:
cognitiveEmpathyAverage:
agreeablenessAverage:
delayedGratificationAverage:
protectionAverage:
acquisitionRate:
assimilationRate:
transformationRate:
exploitationRate:
valenceBefore:
motivationBefore:
valenceDuring:
motivationDuring:
valenceAfter:
motivationAfter:
vBd:
vDa:
vAb:
mBd:
mDa:
mAb:

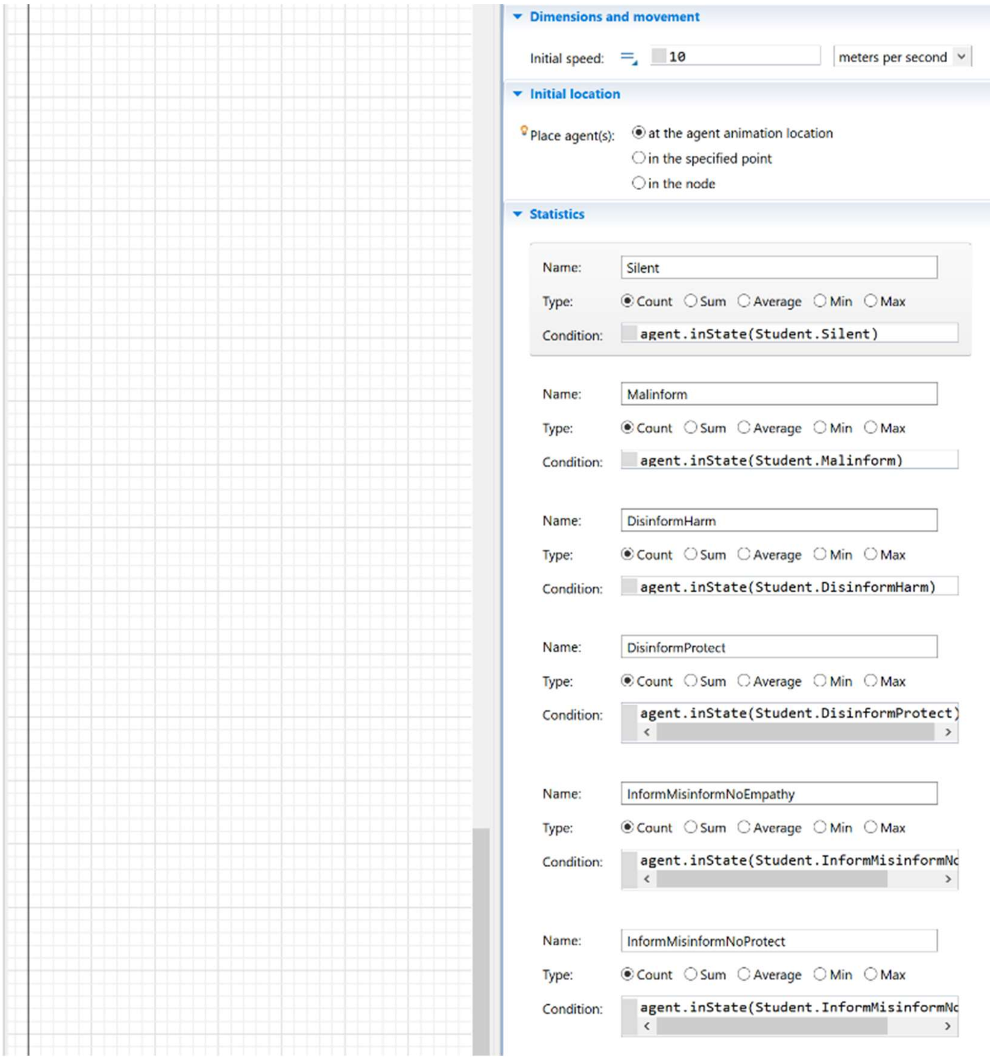


FIGURE 87. IN THE "MAIN - AGENT TYPE" WINDOW, SELECTING THE "LESSON" ICON, "PROPERTIES" TAB, THE "STATISTICS" SECTION HAS ALL THE DIFFERENT STATES BEING COUNTED.

In the "Main - agent type" window, two variables are created which are "collectiveValence" which is where the student's valence value is added and "collectiveMotivation" which is where the student's motivation value is added.

In the "Student - agent type" window, the students' flowchart is modelled. Two variables are created which are "valence" and "motivation" which represent the dimensions of affective state. With the "valence" variable selected, in the property window, in the "Initial value:" textfield, "valenceBefore" is inputted to set the initial value of valence at the start of the simulation to the value of valenceBefore parameter. The same process is used to set the variable "motivation" to "motivationBefore".

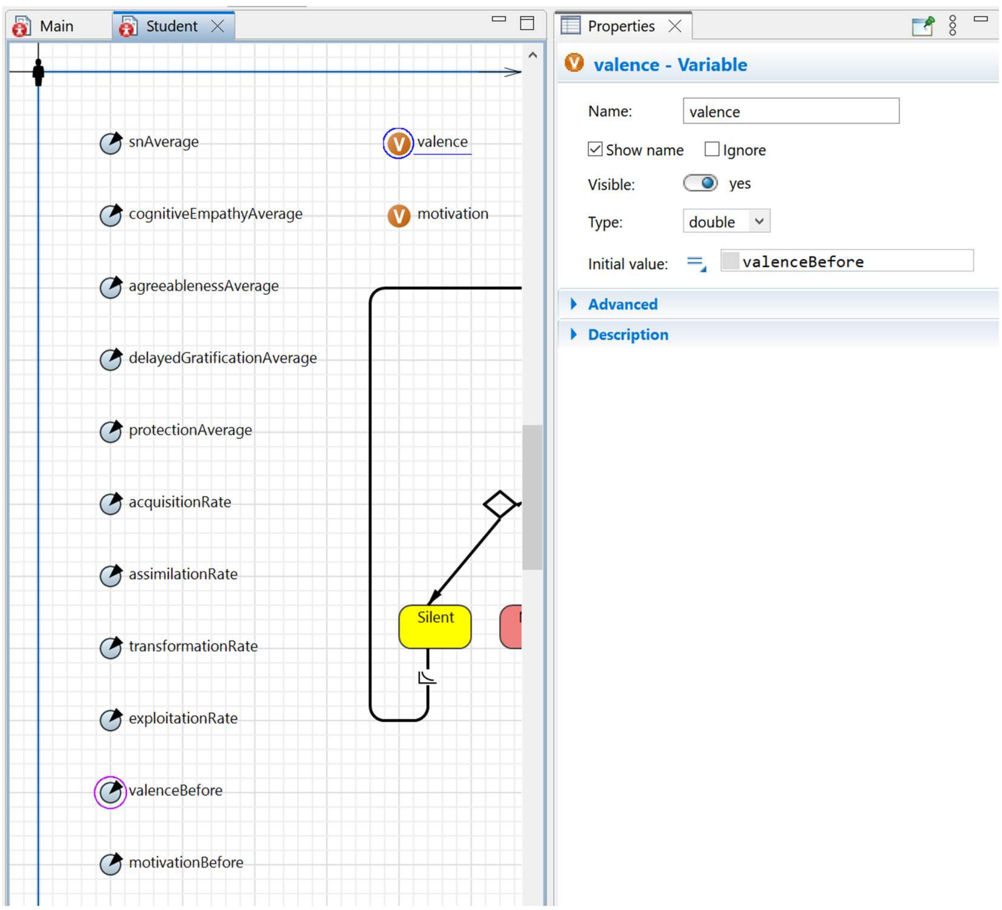


FIGURE 88. IN THE "STUDENT - AGENT TYPE" WINDOW, SELECTING "VALENCE", IN THE "PROPERTIES" TAB, INPUTTING "VALENCEBEFORE" PARAMETER IN THE "INITIAL VALUE:" TEXTFIELD.

A statechart entry point is created. In the property window, “valence+=vBd;motivation+=mBd;main.collectiveValence+=valence;main.collectiveMotivation+=motivation;” is inputted in the “Action:” textfield. The instruction “valence+=vBd;” changes the valence from acquire to assimilate for the student agent. The instruction “motivation+=mBd” changes the motivation from acquire to assimilate. “main.collectiveValence+=valence;main.collectiveMotivation+=motivation;” respectively adds the student agents’ valence and motivation to the collective variables in the “Main - agent type” window. This will allow to keep track of the collective affective states as student agents differ in the ACAP process.

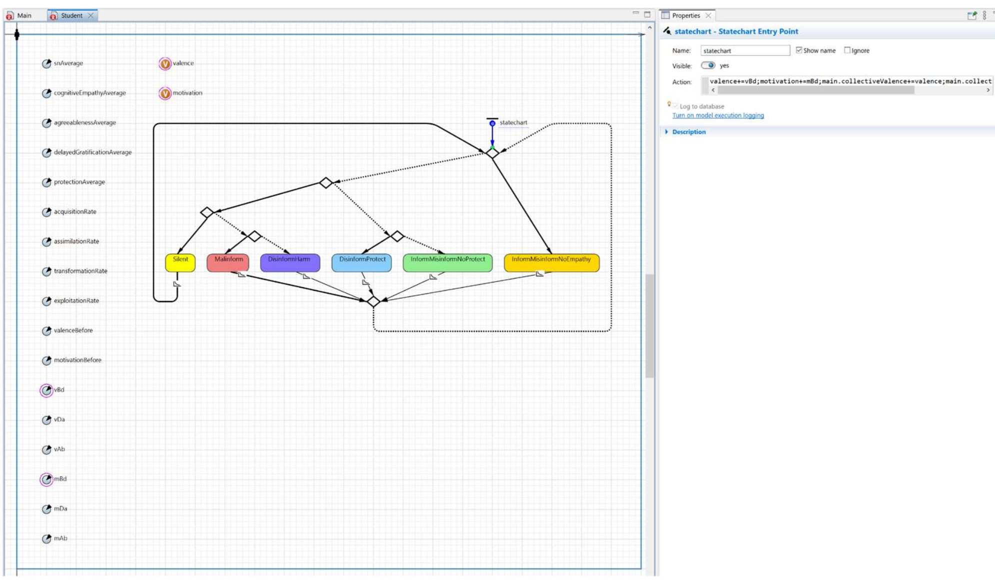


FIGURE 89. IN THE “STUDENT - AGENT TYPE” WINDOW, SELECTING “STATECHART”, IN THE “PROPERTIES” TAB, INPUTTING THE FORMULA IN THE “ACTION:” TEXTFIELD.

The different information disorders are modelled. Preceding these, the branches and the transitions are also created respecting the logic from the diagram in “4. Design Concepts - Representation”. Each branch has two transitions. One transition is left as “Default” so that the flow will default to if the condition of the other branches is not met. For the other transitions, in the property window, the option “Conditional” is selected. In the “Condition:” textfield, the condition statement to take this path is inputted.

For the transition leading to “InformMisinformNoEmpathy”, the condition is set to “cognitiveEmpathyAverage<2.5” which represents the lack of presence of cognitive empathy. For the transition leading to the branch preceding the transition leading to “Silent state”, the condition is set to “valence<0&&motivation>0” which represents the affective state of anger. For the transition leading to “Malinformation”, the condition is set to “delayedGratificationAverage>2.5” which represents the presence of delayed gratification. For the transition leading to “DisinformProtect”, the condition is set to “protectionAverage>2.5” which represents the presence of the motivation to protect.

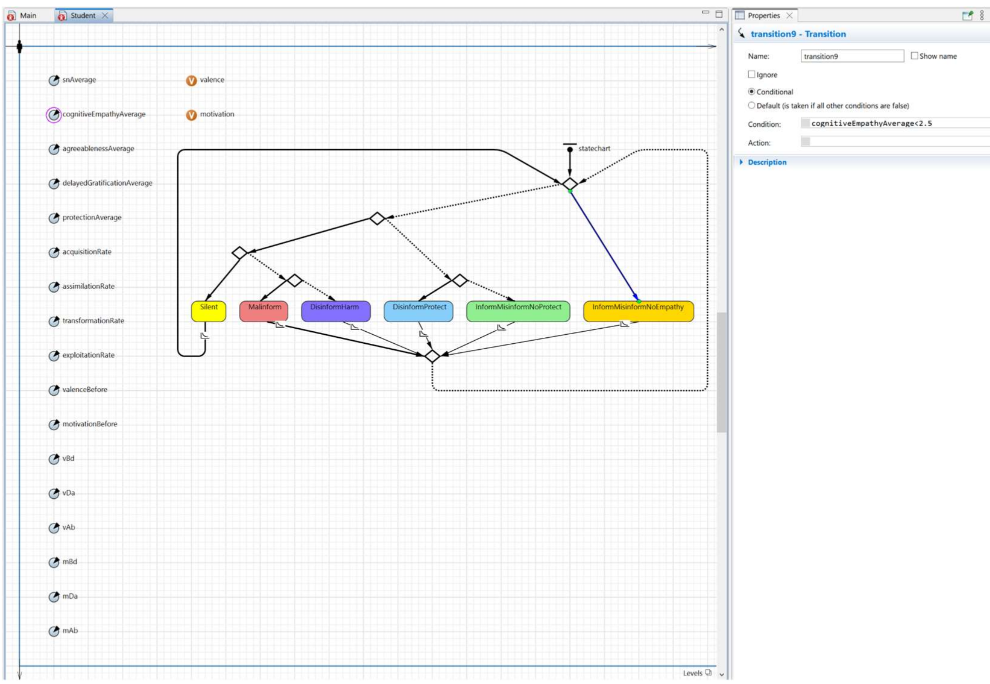


FIGURE 90. IN THE “STUDENT - AGENT TYPE” WINDOW, SELECTING A TRANSITION, IN THE “PROPERTIES” TAB, SELECTING “CONDITIONAL” AND INPUTTING THE CONDITION IN THE “CONDITION:” TEXTFIELD.

Each information disorder state is given their name and a distinct colour. More importantly, in the “Properties” tab for each state, in the “Entry action:” textfield, “shapeBody.setFillColor(“colour”)” is inputted where “colour” is set to the colour of the information disorder so that when the simulation is executed, the agent changes colour. In the “Exit action:” textfield, the formula “valence+=vDa;motivation+=mDa;main.collectiveValence+=valence;main.collectiveMotivation+=m otivation;” is inputted so that the variables of valence and motivation change from assimilate to exploit and the collective affective state also reflects those changes.

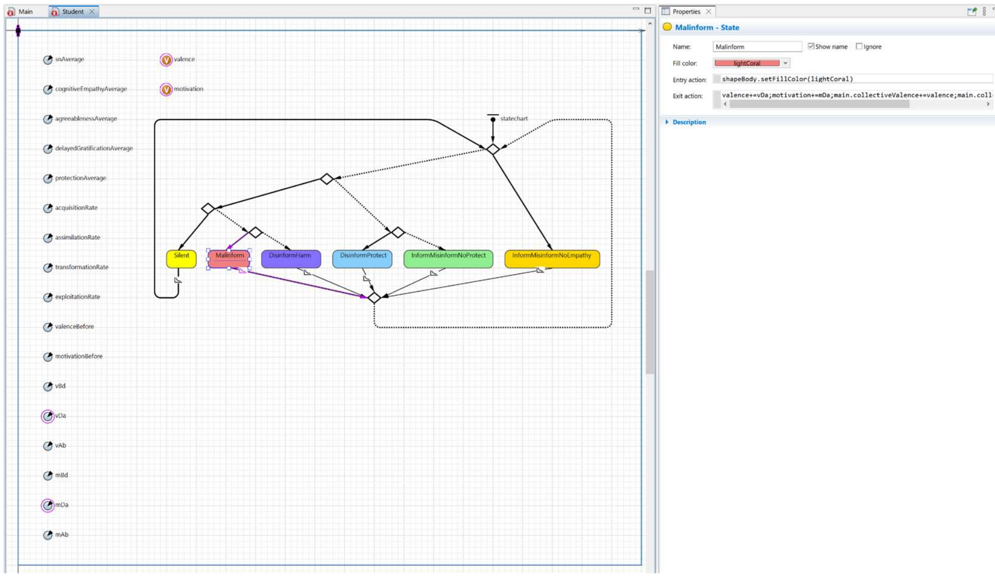


FIGURE 91. IN THE “STUDENT - AGENT TYPE” WINDOW, SELECTING A STATE, IN THE “PROPERTIES” TAB, INPUTTING THE CODE IN THE “ENTRY ACTION:” AND THE “EXIT ACTION:” TEXTFIELDS.

Following each state, the transition is given its corresponding rate parameter. For example, selecting a transition after “Malinformation”, in the “Properties” tab, in the “Transition” section, the “Triggered by:” dropdown box is set to “Rate”, and the “Rate:” textfield is set to the “transformationRate+exploitationRate+snAverage+acquisitionRate+assimilationRate”. This formula is the rate to cycle back from assimilate to assimilate. “transformationRate+exploitationRate” is the rate from assimilate to exploit. “snAverage” is the average social network connection used to represent the rate from exploit to acquire. “acquisitionRate+assimilationRate” is the rate from acquire to assimilation. The transition from “Silent” to the first branch where the “Rate:” is “transformationRate+exploitationRate+acquisitionRate+assimilationRate” where “snAverage” is dropped as “Silent” is used to represent student agents that no longer interact with others because of high agreeableness.

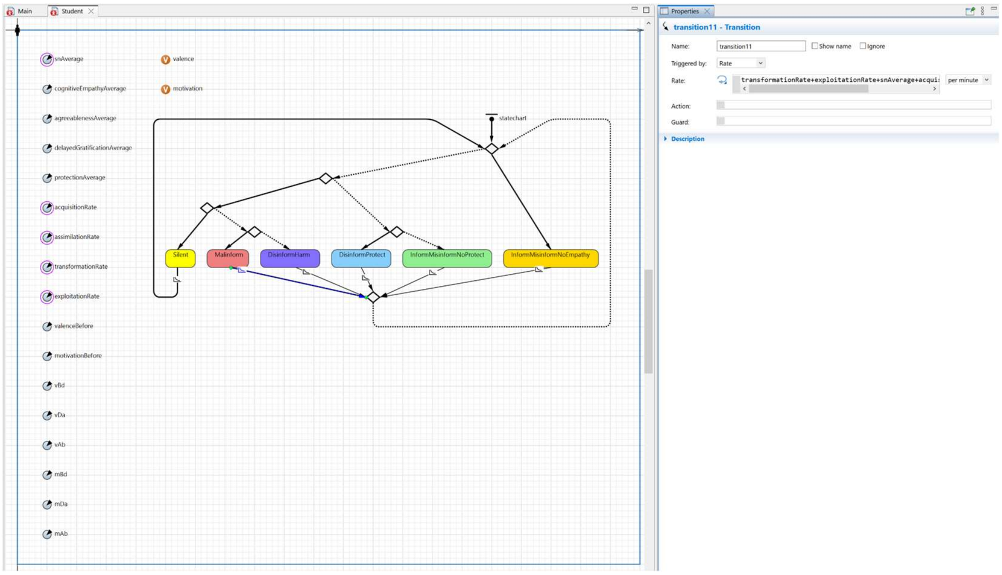


FIGURE 92. IN THE "STUDENT - AGENT TYPE" WINDOW, SELECTING A TRANSITION ARROW AFTER A STATE, "PROPERTIES" TAB, "TRANSITION" SECTION, "TRIGGERED BY:" SET TO "RATE", "RATE:" IS SET TO THE RESPECTIVE FORMULA.

All the transitions following the information disorder states (except for "Silent") converge to a branch which is followed by one transition. This avoids mistakes when re-inputting formulas in the "Action:" textfield as there is only one transition for many information disorder states. In the "Action:" textfield of the single transition, "valence+=vAb*(main.collectiveValence/195)*(snAverage/195)*(cognitiveEmpathyAverage/5);motivation+=mAb*(main.collectiveMotivation/195)*(snAverage/195)*(cognitiveEmpathyAverage/5);valence+=vBd;motivation+=mBd;main.collectiveValence+=valence;main.collectiveMotivation+=motivation;" is inputted. "valence+=vAb*(main.collectiveValence/195)*(snAverage/195)*(cognitiveEmpathyAverage/5);" is the formula for valence change during spillover (See "4.Design Concept - Adaptation - Spillover" section for further information). "motivation+=mAb*(main.collectiveMotivation/195)*(snAverage/195)*(cognitiveEmpathyAverage/5);" is the formula for motivation change during spillover (See "4.Design Concept - Adaptation - Spillover" section for further information).

“main.collectiveValence+=valence;main.collectiveMotivation+=motivation;” reflect the affective state change to the collective valence and motivation.

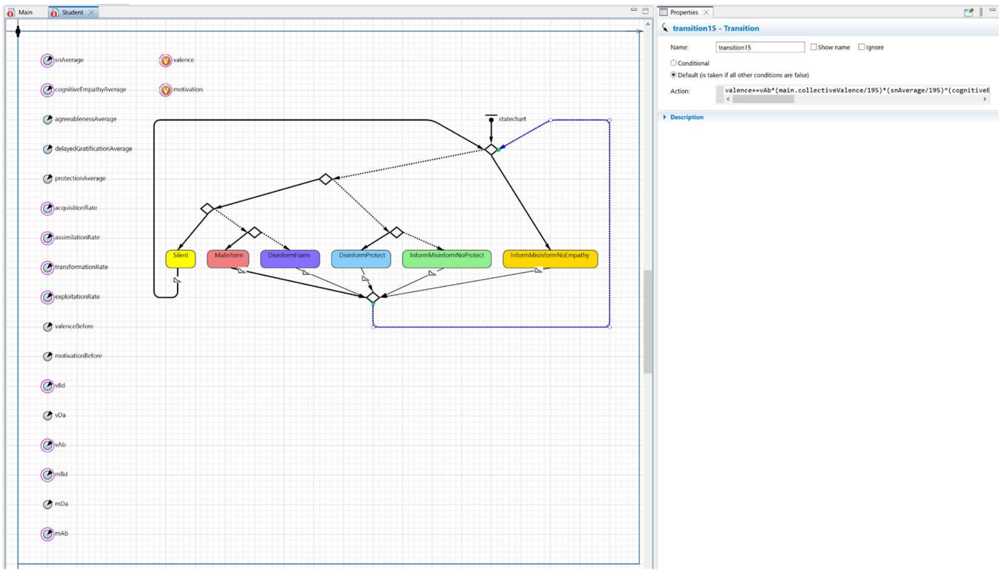


FIGURE 93. IN THE “STUDENT - AGENT TYPE” WINDOW, SELECTING A TRANSITION ARROW FROM THE BRANCH FOLLOWING INFORMATION DISORDERS, “PROPERTIES” TAB, “TRANSITION” SECTION, “ACTION:” IS SET TO THE RESPECTIVE FORMULA.

Again, “Silent” is the exception where its own transition has in the “Action:” textfield inputted “valence+=vAb;motivation+=mAb;main.collectiveValence+=valence;main.collectiveMotivation+=motivation;valence+=vBd;motivation+=mBd;main.collectiveValence+=valence;main.collectiveMotivation+=motivation;”. As people who are silent have high agreeableness, their affective state is not contaminated by the collective affective state.

6. Input Data

The data this experiment uses is the same as the previous experiment, and the survey design is the same. The input data for this experiment is quantitative. The data collection was performed at UTS. 195 records were left after data cleansing.

7. Submodels

There are no important sub-models for this experiment.

8.3.3 Implementation: Execution simulation

The simulation was implemented in AnyLogic 8 Personal Learning Edition 8.9.0 Build: 8.9.0.202404161236 x64, and executed using the data discussed in section 6. Input Data. The simulation was run for a duration of a lesson which is 3 hours or 180 minutes.

Simulation Results

While there are some very big assumptions made in this experiment, the simulation shows a majority of students will disinform to protect themselves. A minority of the students will malinform that is, try to harm in the long-term using truth. The students who malinform fluctuate across the simulation. Inform or misinform out of no need to protect or no empathy is a very small minority and so are students who disinform to harm. Finally, the number of students that remain silent or who have withdrawn from the collective is slow to grow but somewhat on par with the student who malinform. This simulation can be interpreted in many different ways. All these interpretations depend on the logic, parameters, and variables that have been programmed. Once more, this experiment has had to make some heavy assumptions to overcome the limitations to realise its programming. The parameter that is experimented on here is agreeablenessAverage. The different simulations executed show the different values which agreeablenessAverage is measured against.

Agreeableness set to 0

For the transition leading to “Silent”, the condition is set to “agreeablenessAverage>0”. This represents that everyone will be agreeable irrespective of the agent’s value of the “agreeablenessAverage” (see figure 93).

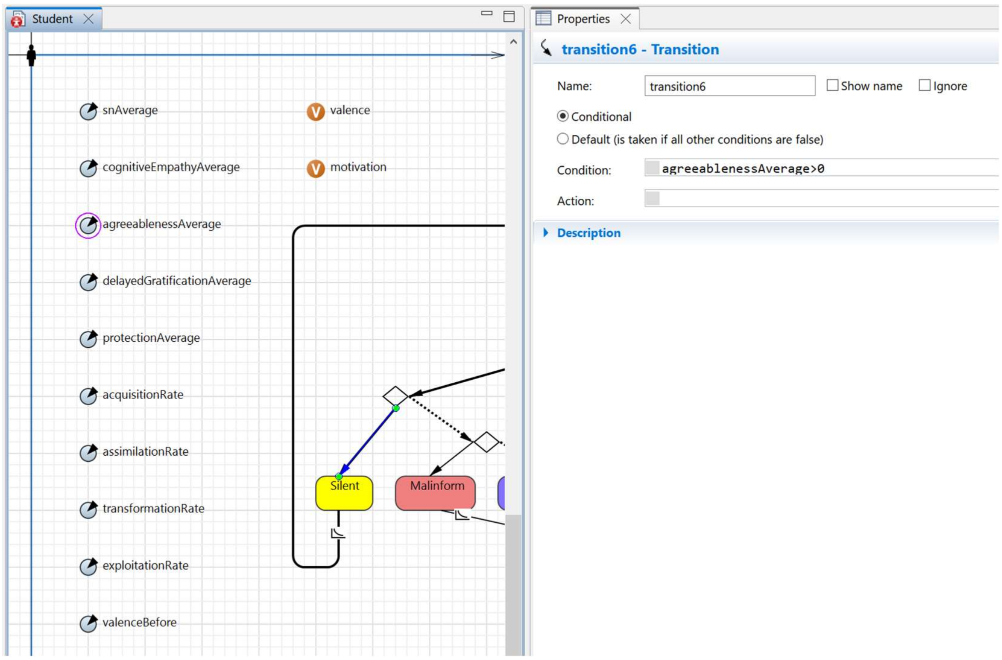


FIGURE 94. SIMULATION SET WHERE SILENT IS “AGREEABLENESSAVERAGE > 0”

The simulation is then compiled and run.

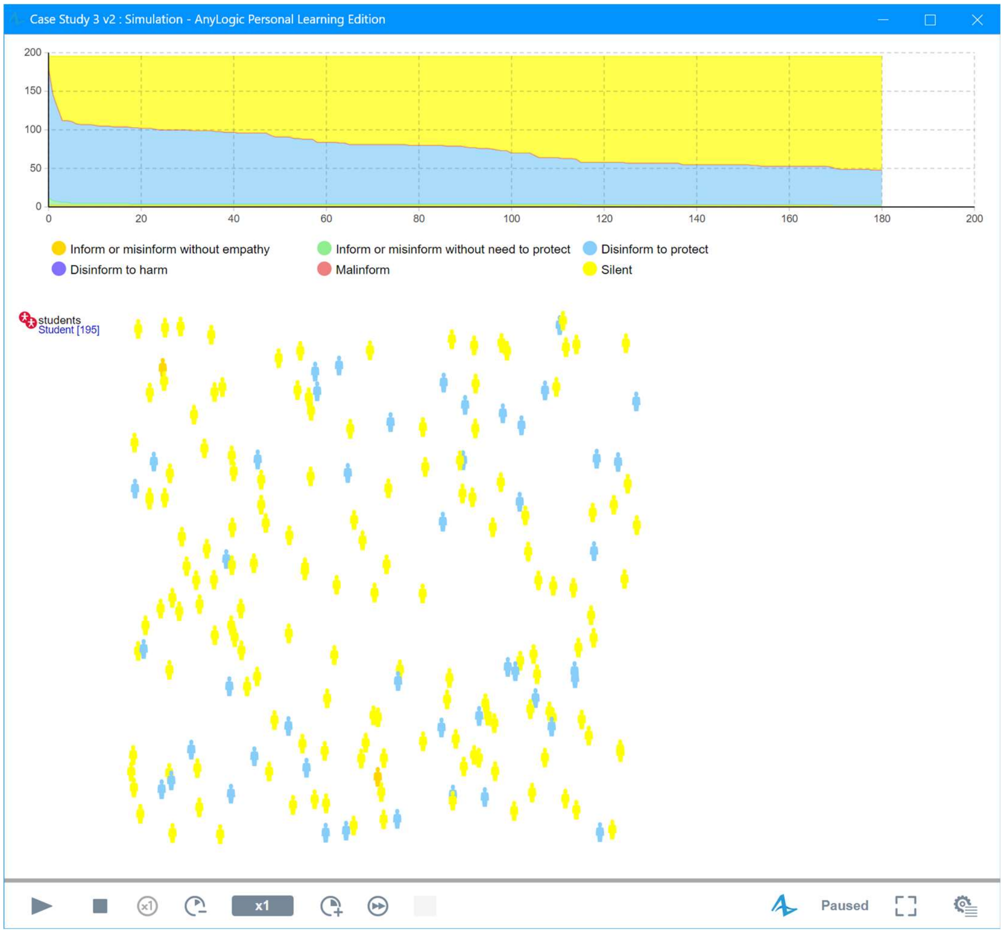


FIGURE 95. SIMULATION RUN FOR THE DIFFUSION OF INFORMATION DISORDER WITH "AGREEABLENESSAVERAGE > 0"

At the end of the simulation where the agreeableness branch condition was set to "agreeablenessAverage > 0", there were 2 agents that were informing or misinforming without empathy (carrying on information without caring), 46 that were disinforming to protect, and 147 that were silent. There were no agents that were informing or misinforming with no will to protect, malinforming, and disinforming to harm.

TABLE 39. NUMBER OF AGENTS BY INFORMATION DISORDER IN SIMULATION WHERE "AGREEABLENESSAVERAGE > 0".

Information Disorder	Number of Agents
Inform or misinform without empathy	2
Inform or misinform with no will to protect	0
Malinform	0
Silent	147
Disinform to harm	0
Disinform to protect	46

Agreeableness set to 1

For the transition leading to "Silent", the condition is set to "agreeablenessAverage>1".

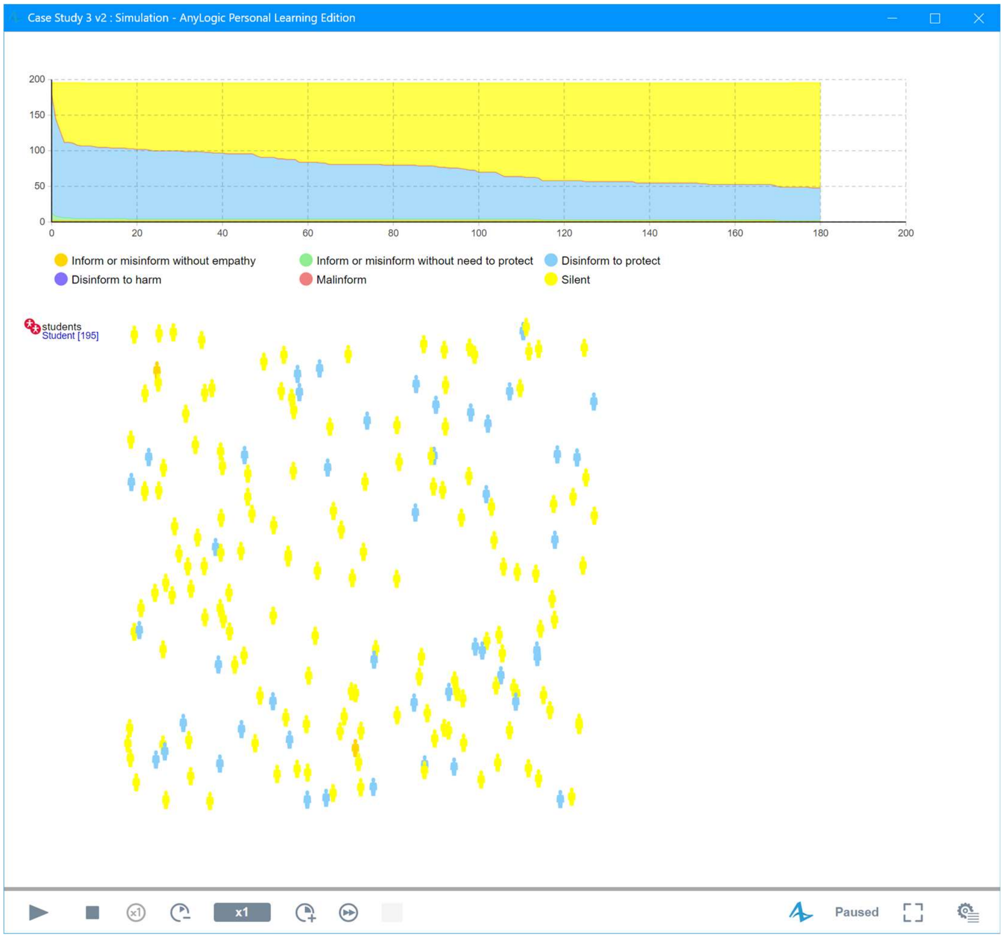


FIGURE 96. SIMULATION RUN FOR THE DIFFUSION OF INFORMATION DISORDER WITH "AGREEABLENESSAVERAGE > 1"

At the end of the simulation where the agreeableness branch condition was set to "agreeablenessAverage > 1", the results were the same as the previous simulation.

TABLE 40. NUMBER OF AGENTS BY INFORMATION DISORDER IN SIMULATION WHERE "AGREEABLENESSAVERAGE > 1".

Information Disorder	Number of Agents
Inform or misinform without empathy	2
Inform or misinform with no will to protect	0
Malinform	0
Silent	147
Disinform to harm	0
Disinform to protect	46

Agreeableness set to 2

For the transition leading to “Silent”, the condition is set to “agreeablenessAverage>2”.

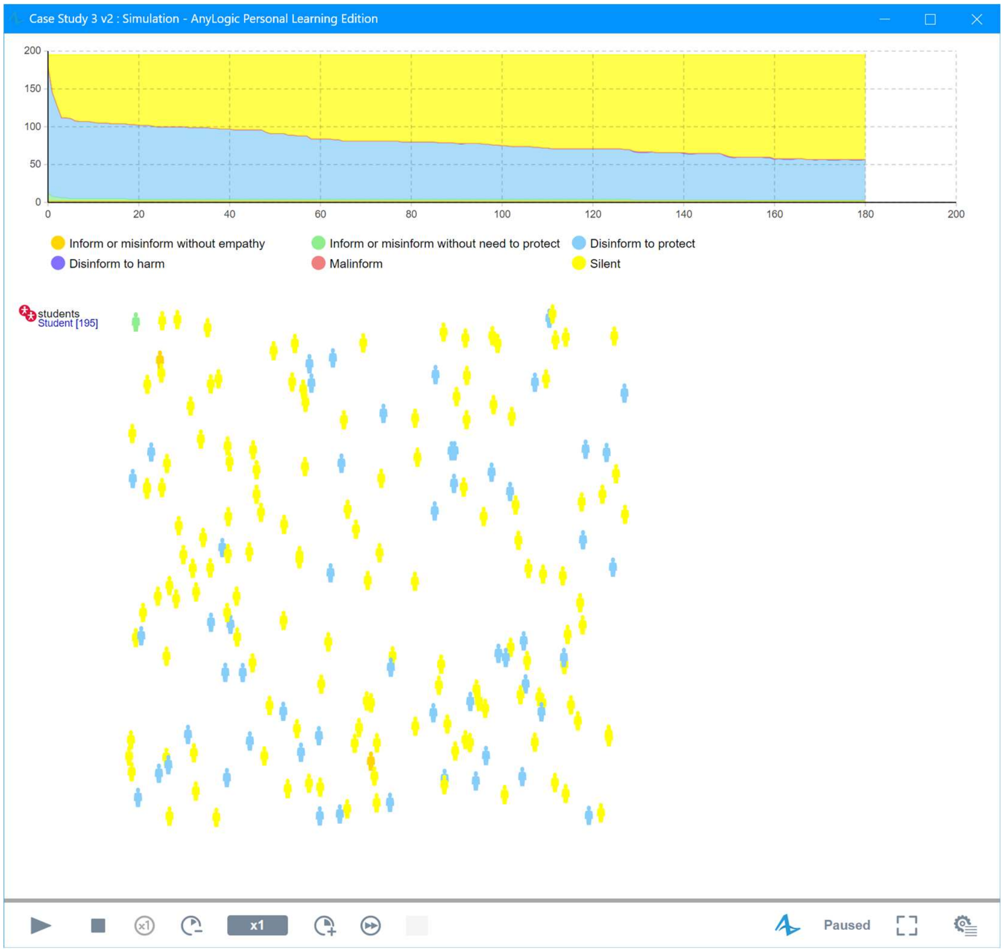


FIGURE 97. SIMULATION RUN FOR THE DIFFUSION OF INFORMATION DISORDER WITH “AGREEABLENESSAVERAGE > 2”

At the end of the simulation where the agreeableness branch condition was set to “agreeablenessAverage > 2”, there were 2 agents that were informing or misinforming without empathy (carrying on information without caring), 1 that were informing or misinforming with no will to protect, 54 that were disinforming to protect, and 138 that were silent. There were no agents that were malinforming, and disinforming to harm. With the increase of the agreeableness branch condition, the number of agents that were informing or misinforming with no will to protect and that were disinforming to protect increased, and the number of agents that were silent decreased.

TABLE 41. NUMBER OF AGENTS BY INFORMATION DISORDER IN SIMULATION WHERE "AGREEABLENESSAVERAGE > 2".

Information Disorder	Number of Agents
Inform or misinform without empathy	2
Inform or misinform with no will to protect	1
Malinform	0
Silent	138
Disinform to harm	0
Disinform to protect	54

Agreeableness set to 3

For the transition leading to “Silent”, the condition is set to “agreeablenessAverage>3”.

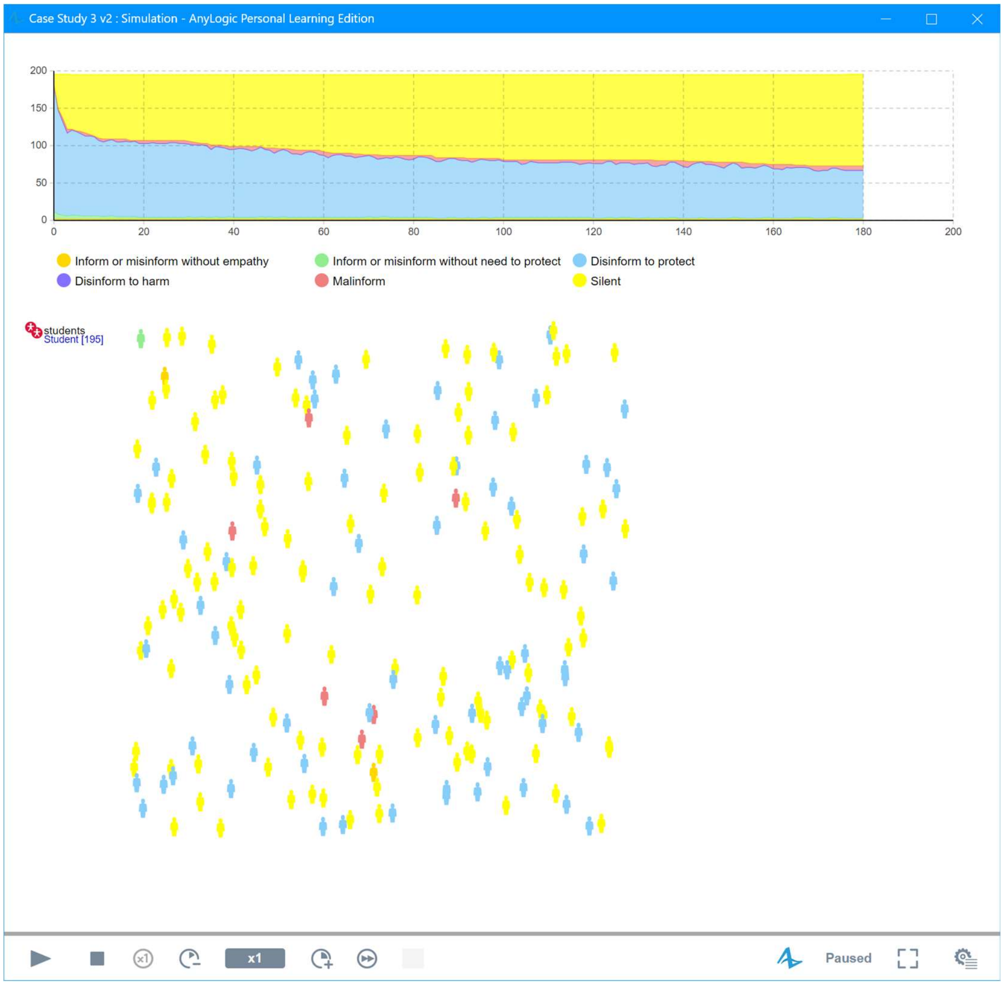


FIGURE 98. SIMULATION RUN FOR THE DIFFUSION OF INFORMATION DISORDER WITH “AGREEABLENESSAVERAGE > 3”

At the end of the simulation where the agreeableness branch condition was set to “agreeablenessAverage > 3”, there were 2 agents that were informing or misinforming without empathy (carrying on information without caring), 1 that were informing or misinforming with no will to protect, 64 that were disinforming to protect, and 122 that were silent, 6 that were malinforming. There were no agents that were disinforming to harm. With the further increase of the agreeableness branch condition, the number of agents that were disinforming to protect further increased, the number of agents that were malinforming increased, and the number of agents that were silent further decreased.

Table 42. Number of agents by information disorder in simulation where “agreeablenessAverage > 3”.

Information Disorder	Number of Agents
Inform or misinform without empathy	2
Inform or misinform with no will to protect	1
Malinform	6
Silent	122
Disinform to harm	0
Disinform to protect	64

Agreeableness set to 4

For the transition leading to “Silent”, the condition is set to “agreeablenessAverage>4”.

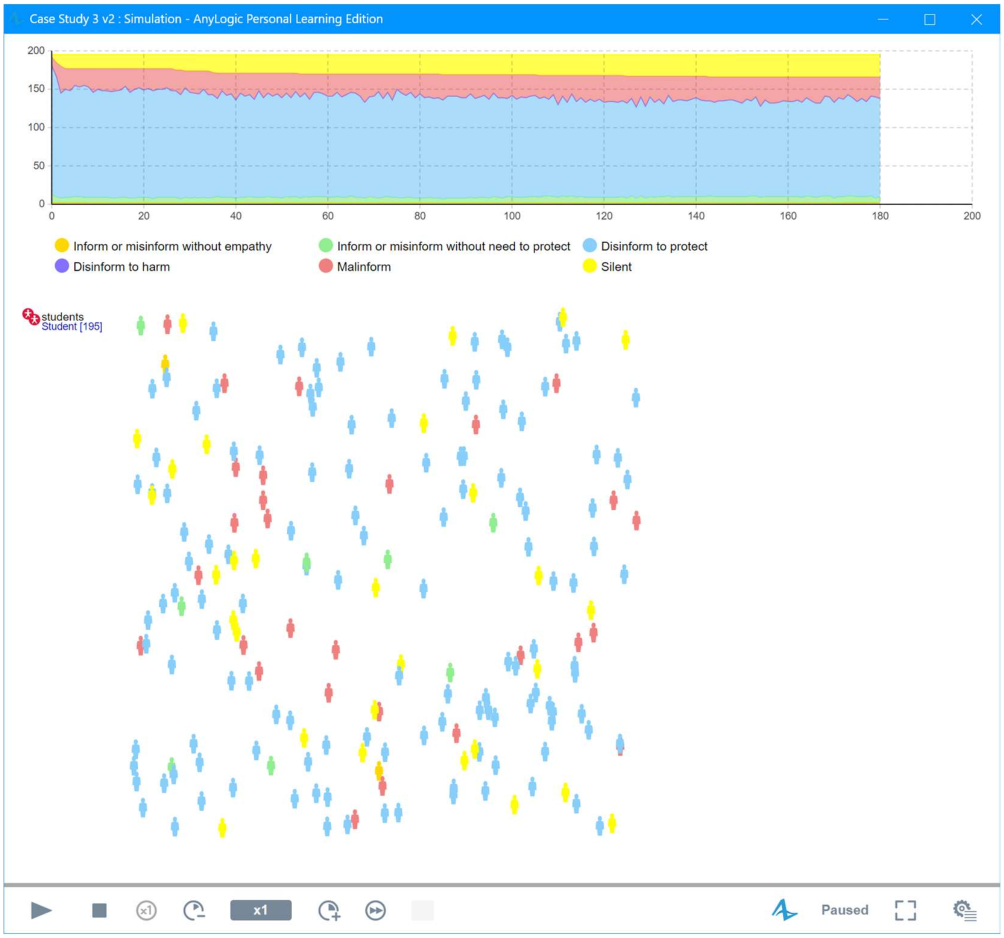


FIGURE 99. SIMULATION RUN FOR THE DIFFUSION OF INFORMATION DISORDER WITH “AGREEABLENESSAVERAGE > 4”

At the end of the simulation where the agreeableness branch condition was set to “agreeablenessAverage > 4”, there were still 2 agents that were informing or misinforming without empathy (carrying on information without caring), 8 that were informing or misinforming with no will to protect, 128 that were disinforming to protect, and 29 that were silent, 28 that were malinforming. There were no agents that were disinforming to harm. With the further increase of the agreeableness branch condition, the number of agents that were informing or misinforming with no will to protect, malinforming, disinforming to protect all further increased, and the number of agents that were silent further decreased.

TABLE 43. NUMBER OF AGENTS BY INFORMATION DISORDER IN SIMULATION WHERE "AGREEABLENESSAVERAGE > 4".

Information Disorder	Number of Agents
Inform or misinform without empathy	2
Inform or misinform with no will to protect	8
Malinform	28
Silent	29
Disinform to harm	0
Disinform to protect	128

Agreeableness set to 5

For the transition leading to "Silent", the condition is set to "agreeablenessAverage>5". This represents that nobody will be agreeable.

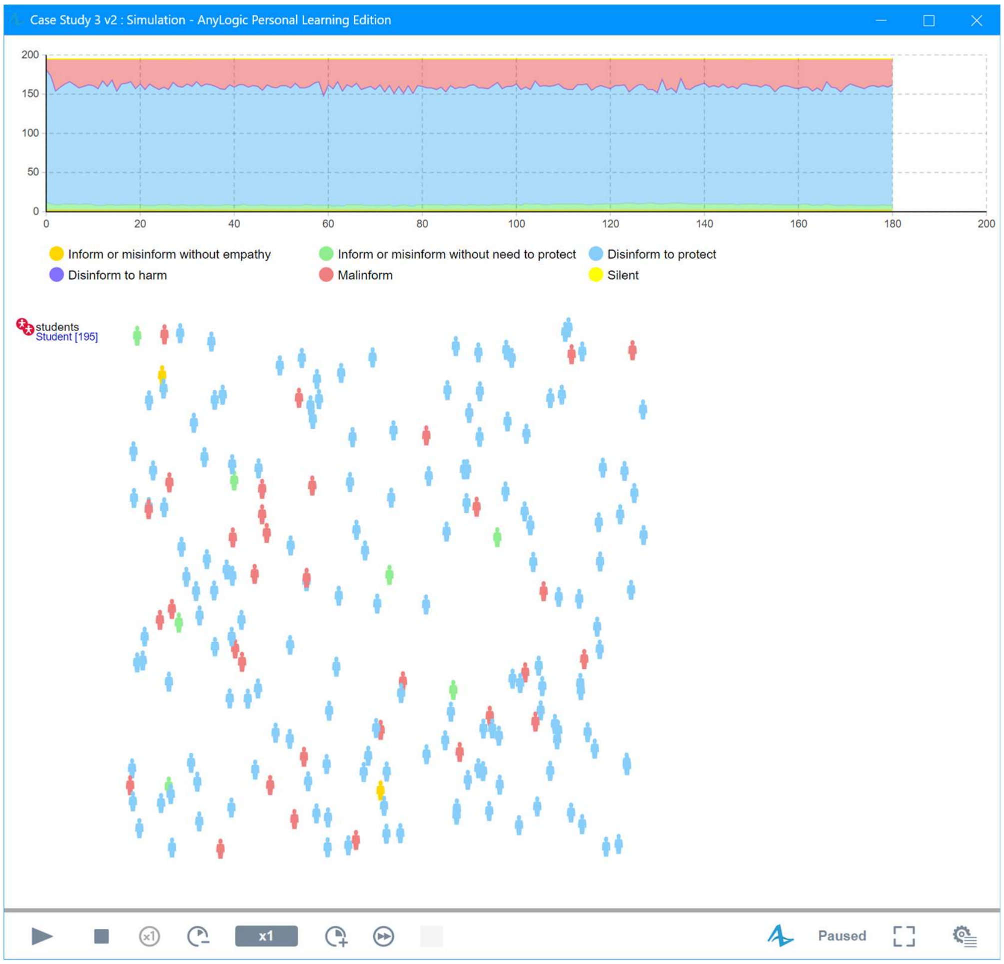


FIGURE 100. SIMULATION RUN FOR THE DIFFUSION OF INFORMATION DISORDER WITH "AGREEABLENESSAVERAGE > 5"

At the end of the simulation where the agreeableness branch condition was set to "agreeablenessAverage > 5", there were still 2 agents that were informing or misinforming without empathy (carrying on information without caring), 7 that were informing or misinforming with no will to protect, 153 that were disinforming to protect, and 0 that were silent, 33 that were malinforming. There were no agents that were disinforming to harm. With the further increase of the agreeableness branch condition to the maximum impossible criteria of 5, the number of agents that were, malinforming, disinforming to protect all further increased, the number of agents that were silent further decreased, and the number of agents that were informing or misinforming with no will to protect decreased.

TABLE 44. NUMBER OF AGENTS BY INFORMATION DISORDER IN SIMULATION WHERE "AGREEABLENESSAVERAGE > 5".

Information Disorder	Number of Agents
Inform or misinform without empathy	2
Inform or misinform with no will to protect	7
Malinform	33
Silent	0
Disinform to harm	0
Disinform to protect	153

8.4 Discussion and Implications of the Results

8.4.1 Hypothesis Results

Hypothesis 3a: Agreeableness increases the spread of information disorders.

Hypothesis 3b: Agreeableness decreases the spread of information disorders.

Observing the simulation where “agreeablenessAverage>0”, malinformation is absent. Observing the simulation where “agreeablenessAverage>3”, while the majority of the students are initially disinforming to protect, the fluctuation of students who are malinforming demonstrates that the intent to harm does corrupt the “stupid” students. Observing the simulation where “agreeablenessAverage>5”, malinforming is at its highest. Comparing each simulation with another, one can observe that without agreeableness malinformation increases. Hypothesis 3a has not been validated. Hypothesis 3b has been validated.

TABLE 45. NUMBER OF AGENTS BY INFORMATION DISORDER FOR EACH SIMULATION.

Information Disorder	Number of Agents where “agreeablenessAverage>0”	Number of Agents where “agreeablenessAverage>1”	Number of Agents where “agreeablenessAverage>2”	Number of Agents where “agreeablenessAverage>3”	Number of Agents where “agreeablenessAverage>4”	Number of Agents where “agreeablenessAverage>5”
Inform or misinform without empathy	2	2	2	2	2	2
Inform or misinform with no will to protect	0	0	1	1	8	7
Malinform	0	0	0	6	28	33
Silent	147	147	138	122	29	0
Disinform to harm	0	0	0	0	0	0
Disinform to protect	46	46	54	64	128	153

8.4.2 Discussion of Results

With agreeableness beginning to disappear (with the increasing condition branch of "agreeablenessAverage > x") agents stop being silent and begin to lie to protect themselves and even malinform. One possible interpretation is that students' empathy without agreeableness corrupts them. As a result, they resort to lying to protect themselves or even withhold information to malinform. Obfuscation should be considered. The students have learned to not fight truth but instead withhold it. Beauvoir (1970) makes the point that truth is conductive of justice. The simulation results demonstrate that information disorder is a powerful instrument that serves the obfuscation of truth. This would have an impact on justice.

8.4.3 Limitations

The simulation in this experiment relied on several significant assumptions. The primary distinction between malinformation and disinformation lies in their respective effects on delayed gratification. Various variables may influence an individual's decision to use malinformation instead of disinformation for harmful purposes, including their IQ, the information available to them, their personal experiences, and their reasoning. The same principle applies to distinguishing between disinformation used for protection and information or misinformation used without any protective intent. Although the PMT instrument and framework may be reliable and valid, its application in this experiment to distinguish between deliberate misinformation used for protection and intentional or unintentional misinformation used without any protective intent is inadequate in capturing the motivations behind why individuals may lie to protect in real-life situations. There are various possible motives for a person to lie in order to safeguard something. For example, individuals might not be able to rely on a swift and affordable judicial system (Cuervo-Cazurra & Rui, 2017; Zhao, 2006). An archetypal illustration is the person who conceals their own sexual orientation due to the lack of support or acceptance within their social environment. Ultimately, the flowchart that depicts the decision-making process for information disorders is based on certain assumptions. Individuals' motivations and justifications are not only influenced by their own circumstances, but also vary in terms of their magnitude, the significance they assign to them, and the specific progression and arrangement in which these choices are made.

8.4.4 Further Recommendation and Conclusion

Out of all the various assumptions made in this experiment, there is one that should be strongly advised. The notion that someone may deliberately spread false information in order to safeguard their own interests, without necessarily intending to cause harm, holds significance. This phrase pertaining to disinformation should be incorporated into the existing framework of information disorder. The simulation study approach is hindered by the simultaneous occurrence of model conceptualisation and data gathering. ABM is significantly constrained by these restrictions. However, this experiment demonstrates that ABM is an appropriate technique for simulating the spread of information disorder. Social media firms possess an abundance of data that surpasses the limitations of a single research student with advanced degrees. Businesses are not obligated to adhere to the same ethical standards as universities. Psychoanalysis could provide a more comprehensive framework for understanding the process of determining information disorder. Beauvoir (1970) does make a solid argument about the context influencing a person's decision. This is, however, a limitation for all social simulations and not the model. The literature in the area of information disorder has not yet expanded into it. This experiment makes the point that ABM would have some benefits should psychoanalysis were to do so. The colour wheel of love from Lee (1973) would be a good starting point. ABM provides many possibilities for research.

Chapter 9: Discussion and Conclusion

9.1 Introduction

This thesis has undertaken the task of researching simulation of knowledge transfer using individual characteristics. As recipient ACAP remains the last barrier to knowledge transfer in an organisation that is not resolved by horizontal structures (Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013), it is focused on in this framework. As an organisation's ACAP is not simply the sum of its members' ACAP (Cohen & Levinthal, 1990), it needed a simulation that could model outliers and minorities. ABM met that requirement. A collective's ACAP is not a simple addition of the different individuals' ACAP cognitive processes. ABM as a simulation method can overcome this. The combination of ABM with individual ACAP in chapter 6 experiment 1 laid the foundation for a knowledge transfer simulation that was heterogeneous. Building on the findings of chapter 6, chapter 7 experiment 2 illustrates that other frameworks and models might be employed to broaden this foundation by including affective states. Following the discovery from chapter 7, chapter 8 experiment 3 expanded upon this concept by examining the spread of information disorder.

9.2 Findings

From chapter 6 experiment 1 to chapter 8 experiment 3, ABM is a robust simulation technique that excels in accurately representing outliers in the model. This thesis aims to model the knowledge transmission using Agent-Based Modelling (ABM) while considering the presence of outliers. Despite the constraints, it has successfully accomplished the task.

9.2.1 Findings from Experiment 1

Experiment 1 addresses the research question 1: "How does interaction between individuals affect organisational knowledge transfer?". As demonstrated in chapter 6, experiment 1 examined the procedure for modelling Agent-Based Modelling (ABM) and its use in simulating knowledge transfer through the usage of the Absorptive Capacity (ACAP). The findings of experiment 1 indicate that people exhibit varying rates of learning, and that social engagement throughout this learning process can reset the learning progress. This has an effect of the collective as shown by the results of the simulation. People need solitude to solidify their learning. Throughout the analysis, design ,and implementation of the ABM in chapter 6, additional discoveries pertain to the use of ROADMAP and ODD in the developmental procedure. Several objects in the ROADMAP exhibit overlap in the ODD and can be used instead of undergoing redevelopment. One possible application of the Goal Model from ROADMAP is in the ODD objective section. Removing repeating items in the process would streamline the development of an ABM making it easier to use and understand.

9.2.2 Findings from Experiment 2

Experiment 2 addresses the research question 2: "Does cognitive empathy affect affective states?". Following the previous experiment, experiment 2 in chapter 7 built upon experiment 1 in chapter 6 by incorporating affective states into the agents in the agent-based model (ABM). The results of experiment 2 illustrate that ABM can be employed to simulate the emotional state of individuals during the learning process. This enables the exploration of cognitive empathy within the simulation which makes it possible to visualise of the diffusion of emotions when empathy was present. This can be utilised to picture the overall emotional state of a group, as well as individual students who may experience fluctuations during the process of transferring knowledge. This allows for the identification of prospective techniques that can be implemented prior to the commencement of a session or course. Additionally, this allows for the inclusion of affective states in simulations using ABM. The ABM has the ability to visually represent an individual's emotions instead of making assumptions. This established the fundamental basis for the subsequent experiments.

9.2.3 Findings from Experiment 3

Experiment 3 addresses the research question 3: "How does high agreeableness affect the diffusion of information disorder?". Finally, following the process of one experiment building from the foundation laid by the previous one, experiment 3 in chapter 8 extended experiment 2 in chapter 7 by creating models of information disorders. The results of experiment 3 demonstrate that ABM can effectively simulate the spread of information disorder and its interplay with other factors. However, this experiment 3 had to make some very important assumptions and restrictions which fall into the limitations of simulation. These assumptions and restrictions have been clearly expressed, as they have the potential to bias the interpretation of said results. However, the utilisation of ABM in this way holds genuine promise that ought to be taken into account for future research. Experiment 3 also makes the point that agreeable personality or one of the interpretations of love reduces malinformation.

9.3 Theoretical and Practical Implications

9.3.1 Theoretical Implications

Knowledge is important and its transfer is time sensitive (Garavelli et al., 2002; Kuo & Lee, 2009; Othman et al., 2014; Vance & Eynon, 1998). Recipients' ACAP is the only common barrier to knowledge transfer (Szulanski, 1996) that is not resolved with horizontal structure (Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013). While organisations are made of persons (Cohen & Levinthal, 1990, p. 131), organisation's knowledge transfer stems from individuals' behaviour (Minbaeva et al., 2012). Cohen and Levinthal (1990, p. 131) makes the point that an organisation ACAP is dependent on its members while not simply being its sum (Jane Zhao & Anand, 2009). Minbaeva et al. (2012) also makes the point that an organisation's knowledge transfer originates from its members' behaviour. ABM allows the simulation of different agents executing different behaviours (Crooks & Heppenstall, 2012). With this research's experiments, the implementation of an ABM to simulate knowledge transfer was proven to be feasible. Experiment 1 showed how agents' learning at different rates or ACAP affected their learning process both individually and collectively which so far was never accomplished. Outside of the technical aspect of this research, experiment 1 demonstrated that bombarding a recipient with information does not allow them time to exploit or apply the knowledge they are trying to absorb. While horizontal structures let communication circulate (Goh, 2002), this is detrimental to a person's ACAP as being bombarded with information prevents individuals the time to reflect on the information they have received (Kuo & Lee, 2009). Experiment 2 demonstrated how to map affective states to the agent's learning process, along with modelling the diffusion of said affective states using cognitive empathy laying the ground work for further modelling that relied on individuals emotions. Experiment 2 also provided the means to visualise individuals' affective states during their learning. The findings showed that the motivation or activation in affective states is not a barrier in knowledge transfer aligned with Szulanski (1996) findings. Experiment 3 showed that modelling could be appended on top of experiment 2 to model the diffusion of information disorders which relied on agents affective states such as anger to trigger intent to harm which is a predecessor to malinformation or disinformation to harm. Experiment 3 modelled information disorder diffusion, this further resulted in showing Foucault (1977, pp. 253-254) 3 types of convicts in organisations. People are in some manner prisoners of knowledge transfer.

9.3.2 Practical Implications

This thesis provides the means to simulate knowledge transfer using individuals ACAP and other characteristics. As a simulation, ABM allows for experimentation where the repercussions can be observed over time (Crooks & Heppenstall, 2012), and thus has no real-world consequences on its participants. This provides a tool to visualise knowledge transfer before it happens in the real world. Chapter 6 experiment 1 provides a means to observe individuals who excessively engage in meetings and discussions without ever progressing to the final phases of absorbing knowledge. This could be valuable in implementing novel KPI in management. This research provides pedagogues with a means to assess knowledge transfer ahead of its activities. Outside of this research there are currently none. For example, teachers planning a class year can now visualise using this research when knowledge transfer might drop. This principle is transferrable to business. For example, a large organisation can now visualise how employees may transfer knowledge in between them as a project commences. This could help when selecting students to form classes or when forming teams at work. Chapter 8 experiment 2 allows for the observation of the transfer of knowledge along with emotional states. This could be utilised in groups that are attuned to emotional sensitivity. For instance, if used in an educational setting, this would enable teachers to effectively monitor potential future results, empowering them to proactively strategize and prioritise instead of depending solely on reactive measures. It could also be applicable in businesses to address psychosocial risk ahead. This might also be good starting point to address psychosocial issue as a social issue rather than a psychological issue. For example, rather than telling a victim of bullying to perform mindfulness meditation, this simulation method could open up the conversation about addressing the bullying from the social context rather than just addressing the victim.

Another noteworthy illustration pertains to the realm of social media. Large social media firms can employ experiment 3 in chapter 8, which involves modelling information disorder, to identify individuals who have the intention to cause harm or are victims of harm. This could be employed in security. This method can help map the transfer of information and its disorders. For example, in a game of social deduction such as Mafia or Blood on the Clocktower, this method could be used to visualise ahead of time the flow of disinformation allowing for better deduction of who the culprit is. This principle is applicable to other stakeholder groups such as politics and policing. This approach can potentially help prevent the spread of disinformation. ABM may have more practical applications in the transfer of knowledge. As technology advances, its performance will improve.

9.4 Limitations

9.4.1 Data Collection and Model Conceptualisation Occur at the Same Time

There had been many different limitations within this research. While the lack of a strict process of development for an ABM can be a problem, there is a much bigger issue with data collection and model conceptualisation. In simulation research design, the model conceptualisation and data collection occur at the same time. Banks et al. (2005) states that data collection can take significant amounts of time and it will change as the model's become more complex. It is highly advisable to start gathering data as early as feasible while conceptualising the model. This recursive situation, sometimes known as a "catch 22" or "chicken and egg problem," creates significant difficulty in generating an appropriate simulation because the data collection can abruptly alter, leading to potential "backtracking". Universities are bound to higher ethical standards than industry. While the ethics application process is at times slow and pedantic, and could be improved in those areas, data collection cannot and must not forsake these ethics otherwise the participants would be the one left to bear the burden and suffer. Industry has a competitive advantage in this area. Social media has immediate access to their customer data and their ethics process is defined by their internal company culture and some government laws. This competitive advantage is however not a benefit.

9.4.2 Simulation Can Never Be Real

The next limitation lies with the nature of a simulation. A simulation can never be more than an estimate or a best guess. Beauvoir (1970, p. 79) in her seminal work writes:

> *"Today as well, every psychoanalyst works at adapting Freudian concepts to suit himself; he attempts compromises; for example, a contemporary psychoanalyst writes: "Whenever there is a complex, there are by definition several components … The complex consists in grouping these disparate elements and not in representing one of them by the others." But the idea of a simple grouping of elements is unacceptable: psychic life is not a mosaic; it is altogether complete in every one of its moments, and this unity must be respected. This is possible only by recovering the original intentionality of existence through the disparate facts. Without going back to this source, man appears a battlefield of drives and prohibitions equally devoid of meaning and contingent. All psychoanalysts systematically refuse the idea of choice and its corollary, the notion of value; and herein lies the intrinsic weakness of the system."*

Any simulation can never be a substitute for real life choice or agency that individuals have within the moment. While the ABM may represent agents, the reality may be very different and an individual or a group should not be neglected in favour of a simulation's results.

9.4.3 Data Collection's Observer Bias

Finally, another limitation is the misinterpretation. Foucault's (1977) statement "Visibility is a trap" has a double meaning. Although the panopticon example is frequently comprehensible, its difficulty lies in the fact that the prison guard's observation was constrained to his own viewpoint. Both the model conceptualisation and data collecting, as well as the simulation outcomes, are susceptible to restrictions and biases that can affect their interpretation.

9.4.4 Conclusion

Although ABM is a potent instrument, it can give rise to significant prejudice if not properly monitored.

9.5 Future Recommendation

ABM is a highly potent tool that is well-suited for simulating the transfer of information. Although the limits are substantial, they can be surmounted with goodwill and effort. Research should explore more efficient methods for integrating data collecting with model conceptualisation. This would alleviate the workload for academics who employ simulation techniques such as Agent-Based Modelling (ABM). Psychoanalysis would greatly benefit from ABM if they resolve their ethical principles. It is crucial for them to address the lack of models that connect collectives, society, justice, and individuals in a timely manner. In the end, the well-being of the individual should never be prioritised over the well-being of the group. However, ABM presents numerous possibilities as long as it is approached with meticulousness.

9.6 Conclusion

Knowledge is critical and its transfer even more so. An arduous relationship between the knowledge holder and recipient, causal ambiguity, and recipient ACAP are the most common barriers to knowledge transfer in organisations (Szulanski, 1996). Horizontal structured organisation allows for communication across business functions or departments unlike their vertical counterpart (Goh, 2002). This appears to be a solution for an arduous relationship, and causal ambiguity (Karlsen & Gottschalk, 2004; Tang et al., 2006; Uygur, 2013). Recipient ACAP remains unresolved. An organisation's ACAP is not simply the sum of the ACAP of its members and yet it is dependent on them (Cohen & Levinthal, 1990). ABM is a simulation method that allows the modelling of outliers and minorities (Crooks & Heppenstall, 2012). It is suitable for modelling knowledge transfer where heterogeneity is key such as recipient ACAP. The development of said model would provide with the means of observing knowledge transfer in a virtual environment rapidly without affecting the real world. This being said, simulations can only be a best guess and there are times when it will fail. This is not however a reason to discount its value and potential. Given that individuals can have different ACAP, experiment 1 showed how social interaction affects said recipient ACAP. Experiment 2 demonstrated how to add another framework onto the initial model. The framework used was affective states. This allowed the modelling and representation of collective affective states using individual affective states and recipient ACAP. Finally, experiment 3 expanded even further by modelling the diffusion of information disorder. All these simulations were executed without affecting real world students. These findings reinforced theoretical theories such as how information saturation is not conductive of knowledge transfer (Kuo & Lee, 2009), how motivation is not a barrier (Szulanski, 1996), and more importantly, complements Foucault (1977, pp. 253-254) 3 types of convicts. The practical implication finally provides practitioners with a tool to visualise knowledge transfer in an organisation ahead of time. This would allow them to instead of reacting, to plan ahead. As technology gets better so will these simulations.

10. Appendix

10.1 Survey Instrument for Experiment 2 and 3

Start of Block: ONLINE SURVEY & PARTICIPANT INFORMATION SHEET

Q323 PARTICIPANT INFORMATION SHEET ETH23-8510- Agent-Based Modelling of Individual Absorptive Capacity for Knowledge and Affective State Transfer WHO IS CONDUCTING THIS RESEARCH? My name is Thomas Dolmark (thomas.dolmark@uts.edu.au) and I am a student at UTS. My supervisor is Dr Osama Sohaib (osama.sohaib@uts.edu.au). WHAT IS THE RESEARCH ABOUT? This research will run a simulation of peoples' emotions and learning. This online survey collects data that is used to populate the simulation with agents or people which will have characteristics that are similar to the real world. This will allow us to see how and when people are affected by information and emotions. WHY HAVE I BEEN INVITED? You have been invited to participate because your contribution may produce results that may benefit you, others around you and the general public. WHAT DOES MY PARTICIPATION INVOLVE? If you decide to participate, we invite you to partake in this survey. ARE THERE ANY RISKS/INCONVENIENCE? We don't expect this questionnaire to cause any harm or discomfort. However the questionnaire may include questions that may make you feel uncomfortable. We have minimise these risks by making this survey voluntary and anonymous, adding responses such as "prefer not to answer" for some of the questions, and ensuring that the questions are articulated in a non aggressive manner. However, if you experience discomfort or distress answering the questions please contact your family doctor or physician, or the following resources: UTS Counselling: uts.ac/counselling UTS self-help resources uts.ac/selfhelp TalkCampus app: uts.ac/talkcampus Lifeline counselling service: 12 11 14 (24-hours) NSW Mental Health Line: 1800 011 511 (24-hours) Please also inform us at thomas.dolmark@uts.edu.au DO I HAVE TO TAKE PART IN THIS RESEARCH PROJECT? Participation in this study is voluntary. It is entirely your decision to take this survey. If you decide not to participate, or to withdraw from the study, it will not affect your relationship with the researchers or the University of Technology Sydney or your school or organisation. Participation or non-participation will have no bearing on student course progression or assessment. WHAT IF I WITHDRAW FROM THIS RESEARCH PROJECT? If you wish to withdraw from the questionnaire once it has started, you can do so at any time without having to give a reason. However, it will not be possible to remove your data from the study once the questionnaire has been completed as the data will not have any means to identify your response. WHAT WILL HAPPEN TO INFORMATION ABOUT ME? By signing the consent form you consent to the research team collecting and using personal information about you for the research project. All this information will be treated confidentially. No identifying information is recorded. We would like to store your information for future use in research projects that are an extension of this research project. In all instances, your information will be treated as confidential and stored securely. It is anticipated that the results of this research project will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that you cannot be identified. No identifying information will be recorded. It will not be possible to ascertain who responded in the survey. In accordance with relevant Australian and/or NSW Privacy laws, you have the right to request access to the information about you that is collected and stored by the research team. You also have the right to request that any information with which you disagree be corrected. Please inform the research team member named at the end of this document if you would like to access your information. The results of this research may also be shared through open access (public) scientific databases, including internet databases. This will enable other researchers to use the data to investigate other important research questions. Results shared in this way will always be de-identified as this survey is anonymous by not recording any personal information (e.g. name, address, date of birth etc.). WHAT IF I HAVE ANY QUERIES OR CONCERNS? If you have queries or concerns about the research that you think I can help you with, please feel free to contact me on thomas.dolmark@uts.edu.au

NOTE: This study has been approved in line with the University of Technology Sydney Human Research Ethics Committee [UTS HREC] guidelines. If you have any concerns or complaints about any aspect of the conduct of this research that you wish to raise independently of the research team, please contact the Ethics Secretariat on ph.: +61 2 9514 2478 or email: Research.Ethics@uts.edu.au], and quote the UTS HREC reference number. Any matter raised will be treated confidentially, investigated and you will be informed of the outcome.

Q1 CONSENT FORM ETH23-8510- Agent-Based Modelling of Individual Absorptive Capacity for Knowledge and Affective State Transfer. I agree to participate in the research project being conducted by Thomas Dolmark at thomas.dolmark@uts.edu.au I have read the Participant Information Sheet or someone has read it to me in language that I understand. I understand the purposes, procedures and risks of the research as described in the Participant Information Sheet. I have had an opportunity to ask questions and I am satisfied with the answers I have received. I freely agree to participate in this research project as described and understand that I am free to withdraw at any time without affecting my relationship with the researchers or the University of Technology Sydney or my school or organisation. I am aware that I can contact Thomas Dolmark at thomas.dolmark@uts.edu.au if I have any concerns about the research.
Tick this box if you consent

▢ I have read the participant information sheet and the consent form, understood its content, and agree to proceed with this survey. (1)

End of Block: ONLINE SURVEY & PARTICIPANT INFORMATION SHEET

Start of Block: Demographic Questions

Q2 What gender do you identify as ?

- ○ Prefer not to say (1)
- ○ Male (2)
- ○ Female (3)
- ○ Non-binary (4)
- ○ I don't know (5)
- ○ Other: (6) ____

Q3 What is your age ?

○ Prefer not to say (1)

○ Under 18 (2)

○ 18 - 24 (3)

○ 25 - 34 (4)

○ 35 - 44 (5)

○ 45 and above (6)

○ I don't know (7)

Q4 Are you a domestic or international student ?

○ Prefer not to say (1)

○ Domestic (2)

○ International (3)

○ I don't know (4)

○ Other: (5) ____

Q5 What are you currently studying ?

- ◯ Prefer not to say (1)
- ◯ I don't know (2)
- ◯ Undergraduate degree (3)
- ◯ Postgraduate degree (4)
- ◯ Research degree (5)
- ◯ Other: (6) ____

End of Block: Demographic Questions

Start of Block: Social Network Scale

Q6 Considering the people to whom you are related either by birth or marriage...

Q7

How many relatives do you see or hear from at least once a month?

◯ None (1)

◯ One (2)

◯ Two (3)

◯ Three or four (4)

◯ Five to eight (5)

◯ Nine or more (6)

Q8

How many relatives do you feel close to such that you could call on them for help?

○ None (1)

○ One (2)

○ Two (3)

○ Three or four (4)

○ Five to eight (5)

○ Nine or more (6)

Q9

How many relatives do you feel at ease with whom you can talk about private matters?

○ None (1)

○ One (2)

○ Two (3)

○ Three or four (4)

○ Five to eight (5)

○ Nine or more (6)

Page Break

Q10 Considering all of your friends including those who live in your neighborhood...

Q11 How many of your friends do you see or hear from at least once a month?

- ○ None (1)
- ○ One (2)
- ○ Two (3)
- ○ Three or four (4)
- ○ Five to eight (5)
- ○ Nine or more (6)

Q12 How many friends do you feel close to such that you could call on them for help?

○ None (1)

○ One (2)

○ Two (3)

○ Three or four (4)

○ Five to eight (5)

○ Nine or more (6)

Q13

How many friends do you feel at ease with whom you can talk about private matters?

○ None (1)

○ One (2)

○ Two (3)

○ Three or four (4)

○ Five to eight (5)

○ Nine or more (6)

End of Block: Social Network Scale

Start of Block: Trust

Q14 Most people are honest.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q15 Most people are trustworthy.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q16 Most people are good and kind.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q17 Most people are trustful of others.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q18 I am trustful.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q19 Most people will respond in kind when they are trusted by others.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

End of Block: Trust

Start of Block: Cognitive Empathy

Q20 I can understand my friend's happiness when they do well at something.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q21 I find it hard to know when my friends are frightened.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q22 When someone is feeling "down" I can usually understand how they feel.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q23 I can usually work out when my friends are scared.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q24 I can often understand how people are feeling even before they tell me.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q25 I can usually work out when people are cheerful.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q26 I can usually realize quickly when a friend is angry.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q27 I am not usually aware of my friend's feelings.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

Q28 I have trouble figuring out when my friends are happy.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

End of Block: Cognitive Empathy

Start of Block: Agreeableness

Q29 I am interested in people.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q30 I sympathize with others' feelings.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q31 I have a soft heart.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q32 I take time out for others.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q33 I feel others' emotions.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q34 I make people feel at ease.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q35 I am not interested in others.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q36 I insult people.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q37 I am not interested in other people's problems.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q38 I feel little concern for others.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

End of Block: Agreeableness

Start of Block: Delayed Gratification Survey

Q39 I would have a hard time sticking with a special, healthy diet.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

Q40 I try to spend my money wisely.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

Q41 I have given up physical pleasure or comfort to reach my goals.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q42 I try to consider how my actions will affect other people in the long-term.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q43 I cannot be trusted with money.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q44 I do not consider how my behavior affects other people.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q45 I cannot motivate myself to accomplish long-term goals.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q46 I have always tried to eat healthy because it pays off in the long run.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q47 When faced with a physically demanding chore, I always tried to put off doing it.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q48 I have always felt like my hard work would pay off in the end.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

End of Block: Delayed Gratification Survey

Start of Block: Protection Motivation Theory

Q49 I am vulnerable to the harmful effects of others' intent to harm me.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q50 I am a victim of others' intent to harm me.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q51 I am threatened by others' intent to harm me.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Page Break

Q52 It is likely that I would gain benefits for not confronting others' intent to harm me.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q53 I could benefit from not confronting others' intent to harm me.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q54 I benefit financially for choosing not to confront others' intent to harm me.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Page Break

Q55 I will be able to find ways to deal with others' intent to harm me.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q56 I know how to deal with situations where others intend to harm me.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q57 I believe I can manage unexpected situations where others' intent to harm me might bring.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Page Break

Q58 It is very expensive for me to respond to others' intent to harm me.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q59 It is very time-consuming for me to respond to others' intent to harm me.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q60 Too much effort is needed for me to respond to others' intent to harm me.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Page Break

Q61 I am sure that responding to others' intent to harm me can have a positive effect in my social context.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q62 I am confident that together my social context can cope with situations where others' intend to harm me.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q63 I can do nothing to help control the situation where others' intend to harm me.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

End of Block: Protection Motivation Theory

Start of Block: Cognitive Style

Q64 I enjoy being methodical and consistent in the way I tackle problems.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

Q65 I enjoy paying strict regard to the sequence of steps needed for the completion of a job.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q66 I enjoy being strict on the production of results, as and when required.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q67 I enjoy being precise about the production of results and reports.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Page Break

Q68 I enjoy pursuing a problem, particularly if it takes me into areas I do not know much about.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q69 I enjoy linking ideas that stem from more than one area of investigation.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q70 I enjoy being fully occupied with what appear to be novel methods of solution.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q71 I enjoy searching for novel approaches not required at the time.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q72 I enjoy struggling to make connections between apparently unrelated ideas.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q73 I enjoy spending time tracing relationships between disparate areas of work.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

End of Block: Cognitive Style

Start of Block: Absorptive Capacity

Q74 I am always actively looking for new knowledge.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q75 I intentionally search for knowledge in many different areas to look “outside the box”.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q76 I am good at distinguishing between profitable and not-so-profitable information or opportunities.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q77 I easily identify what new knowledge is most valuable.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Page Break

Q78 I frequently share my new knowledge with others to establish a common understanding.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q79 I translate new knowledge in such a way that others can understand what I mean.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q80 I communicate newly acquired knowledge that might be of interest to my social context.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Page Break

Q81 I often sit together with others to come up with good ideas.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q82 I meet with people from different experiences to come up with new ideas.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q83 I develop new insights from the knowledge that is available within my social context.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q84 I can turn existing knowledge into new ideas.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Page Break

Q85 I often apply newly acquired knowledge.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q86 I exploit new knowledge to create new products, services, or methods.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q87 I constantly consider how I can apply new knowledge to improve.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

End of Block: Absorptive Capacity

Start of Block: Learning Emotions

Q88 I enjoy being in class.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q89 I am confident when I go to class.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q90 I am proud of myself.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q91 I am angry.

Strongly disagree (1)

Disagree (2)

Neutral (3)

Agree (4)

Strongly agree (5)

Q92 Thinking about class makes me feel uneasy.

Strongly disagree (1)

Disagree (2)

Neutral (3)

Agree (4)

Strongly agree (5)

Q93 I get embarrassed.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q94 I feel hopeless.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q95 I get bored.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Page Break

Q96 I enjoy acquiring new knowledge.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q97 I have an optimistic view toward studying.

- ◯ Strongly disagree (1)
- ◯ Disagree (2)
- ◯ Neutral (3)
- ◯ Agree (4)
- ◯ Strongly agree (5)

Q98 I'm proud of my capacity.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q99 Studying makes me irritated.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q100 I get tense and nervous while studying.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q101 I feel ashamed that I can’t absorb the simplest of details.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q102 I feel hopeless when I think about studying.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q103 The material bores me to death.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Page Break

Q104 For me, the test is an enjoyable challenge.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q105 I have great hope that my abilities will be sufficient.

- Strongly disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly agree (5)

Q106 I'm proud of how well I mastered the exam.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q107 I feel very relieved.

- ○ Strongly disagree (1)
- ○ Disagree (2)
- ○ Neutral (3)
- ○ Agree (4)
- ○ Strongly agree (5)

Q108 I am fairly annoyed.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

Q109 I feel panicky when writing an exam.

◯ Strongly disagree (1)

◯ Disagree (2)

◯ Neutral (3)

◯ Agree (4)

◯ Strongly agree (5)

Q110 I feel ashamed.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

Q111 I have lost all hope that I can do well on the exam.

○ Strongly disagree (1)

○ Disagree (2)

○ Neutral (3)

○ Agree (4)

○ Strongly agree (5)

End of Block: Learning Emotions

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