A Reference Model to Facilitate Collaboration in Human Behaviour Representation for Security and Defence Simulation Modelling

Susan K Aros
Naval Postgraduate School
555 Dyer Rd., Monterey CA 93943
UNITED STATES

skaros@nps.edu

Naomi Betts
Defence Science and Technology Laboratory (DSTL)
Portsdown West, Portsdown Hill Road,
Fareham, Hampshire, PO17 6AD
UNITED KINGDOM

nbetts@dstl.gov.uk

David Robson
QinetiQ Training & Simulation Ltd
Building A7 / 2008B, Cody Technology Park,
Old Ively Road, Farnborough, Hampshire, GU14 0LX
UNITED KINGDOM

david.robson@t-s.qinetiq.com

ABSTRACT

Complexities of human behaviour can cause unexpected outcomes in security and defence operations. In order to better understand the range of potential complications and outcomes it is essential to leverage constructive simulation in order to move beyond the real-world limitations of time and space. To date, however, there has been limited representation of the nuances of effects, both kinetic and non-kinetic, on human behaviour in defence modelling and simulation. This ongoing challenge is being addressed by researchers across multiple disciplines and countries, but collaboration is hampered by different conceptual approaches, knowledge systems, terminology and, in some cases, different definitions for the same terminology. In this paper we cover essential definitions for constructive simulation modelling of human behaviour and present a context-agnostic agent behaviour reference model developed during NATO MSG-198. In the presentation of this model we establish common concepts and terminology to aid in cross-disciplinary discussions of human behaviour modelling in constructive simulations. We then present examples to demonstrate how this reference model can be used to establish common ground for human behaviour modelling across different simulation disciplines, approaches, and application areas.

1.0 OVERVIEW

Defence operational environments are becoming increasingly complex, both in terms of the physical operating environment and operational effects on force behaviour [1]. Modelling and Simulation (M&S) serves as an important tool for NATO and NATO Partner Nations, to enable more effective and efficient joint, collective and coalition training, mission preparation and decision support [2]. To date there has been limited representation of the nuances of human behaviour in increasingly complex operating environments, and the impact of both kinetic and non-kinetic effects on behaviour [3].

A significant challenge in this area is that human behaviour models are currently developed for specific situations and specific M&S applications [3]. This approach is not only an inefficient use of time and resources, but it leads to an inconsistent approach towards representing human behaviour. Therefore, there is a need to compose models that can be used and reused across M&S applications in a more timely and coherent manner. Efficient and effective use of M&S resources is critical to sustain the asymmetrical advantage that simulation provides to NATO and its Partners. Additionally, a wide range of professional disciplines, (including computer science, sociology and psychology [4]) conduct work on human behaviour representation in constructive simulations. Each have different language and knowledge systems, and different perspectives of the issues and challenges related to a topic [5], [6], [7].

In constructive simulations, 'humans' are represented as agents using differing levels of authenticity. The degrees of abstraction can vary widely [3]. Models can be very simple, focussing on one or few factors that impact behaviour, or they can be more complex, incorporating many factors. Models can be composed as simply as stimulus-response pairings (i.e., when *x* comes into proximity, behaviour *y* is enacted) or as complex as an interaction of many factors representing various human cognitive, emotional and social characteristics and processing, which result in the representation of much more complex behaviours. Furthermore, ‘humans’ are represented as agents with varying levels of aggregation [3]: a single agent may represent a single human or a group of individuals of any size (e.g. a single agent may represent a military platoon). Often, large-scale simulations aggregate individuals to avoid excessively high computer simulation processing demands. In addition, one agent could also represent a non-human entity combined with, or controlled by, a human determining its behaviour, such as an agent representing a vehicle with a human driver or an unmanned aircraft being flown remotely by a human pilot. Decisions about the degree of complexity and methods of computer simulation composition are driven by context specific needs, disciplinary perspectives about which factors of human behaviour are most important to represent, and computing resources available.

These differences in language, approaches and understanding of human behaviour make it difficult for different disciplines to collaborate, particularly when they model different aspects of human behaviour in different contexts. Each discipline may have a valid but incomplete understanding; a symmetry of ignorance [8]. By exploiting the symmetry of ignorance a diverse group can co-construct a new, more comprehensive understanding.

In this paper we first define key terms and then provide an overview of the Agent Behaviour Reference Model (ABRM) developed by the MSG-198 team. Following that we detail two different examples to demonstrate how the ABRM can be used to represent the human behavioural models contained within two defence-related simulation models that differ from each other on a number of key characteristics. In this way we demonstrate the use of the ABRM to establish a common language and structure that can facilitate interdisciplinary collaboration amongst researchers and practitioners across countries, disciplines, and application areas.

2.0 AGENT BEHAVIOUR REFERENCE MODEL

In order to facilitate interdisciplinary collaboration MSG-198 Composable Human Behaviour in Constructive Simulations Specialist Team developed the ABRM to provide a common language and framework for discussing the design of agents driven by human behaviour [3]. The ABRM is an abstract context-agnostic model outlining the most basic but key components to human behaviour modelling, and relationships between those components. Models are typically specific to a context or need, therefore users will expand on the various component details (as required for their needs) using this framework as a basic blueprint. This paper will provide a brief overview of the ABRM and illustrate two examples. A full description of the ABRM can be found in the NATO MSG-198 report "Composable Human Behaviour Representation in Constructive Simulation Systems" [3].

When discussing simulation models that represent human behaviour the terms *entity*, *agent*, and *behaviour* are commonly used; however, different people may use these terms to refer to slightly different, or even somewhat different, things. Therefore, we begin this section with definitions for these important terms. We follow that with a presentation of the ABRM.

2.1 Definitions

An *entity* is any specific 'thing' that is defined and given attributes in the simulation model, and can be used to describe animate or inanimate objects at any level of aggregation. An *agent*, specifically, is an entity that has agency. Agency is the characteristic that provides the entity with "the capacity, condition, or state of acting or of exerting power" [9] that can have an effect on their environment. An agent makes decisions based on interactions with others and the environment within the simulation.

Building on these terms, MSG-198 defined behaviour as "*the perceivable response of an entity with agency to various stimuli in the context of constructive simulation*" [3]. In this definition of behaviour there is an emphasis on responses being externally perceivable by other agents within the system. Perceivability of behaviour is a function of both the agent emitting the behaviour and the agent observing or recording the behaviour, so the determination of what is perceivable is dependent upon the design of the agents and the environment. Any unperceivable responses can only have an effect on the source agent themselves.

2.2 ABRM Description

The ABRM is presented from the perspective of a single agent, referred to as the *Self-Agent*. The ABRM structure is used to document a model of human behaviour, producing a specific Agent Behaviour Model (ABM) for that self-agent. When the ABRM is used to document a conceptual model, there will be a separate ABM for each type or class of agent. When a computer simulation model is then developed, there will be a separate ABM for each instantiated agent.

The ABRM consists of four model components connected by effects arcs and information arcs. Two of these components combined represent all state variables in the simulation model: State of Self and State of World. The **State of Self** (SoS) component represents the set of all state variables describing the self-agent. SoS variables can include affective, motivational, cognitive and physical factors such as: fear and anger, hunger and goals, knowledge, beliefs and values, and position and speed. Aspects of SoS may or may not be perceivable by others, and an individual's degree of control over these internal states may vary. The **State of World** (SoW) component represents the set of state variables describing the world which, from the perspective of the Self-Agent, consists of all state variables not already described in the State of Self. State variables describing the environment can include a wide variety things. Aspects of the environment can be considered through the categories of Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, and Time (PMESII-PT). The SoW also includes all of the states of all other agents in the simulation model apart from the self-agent.

The **Agent Information Processing** component represents the internal processing of the self-agent. This component uses information about the Self-Agent and the World and produces the response of the Self-Agent using some type of logic structures or math functions. The Agent Information processing component can be modelled in a variety of ways such as simple stimulus-response, decision trees, Bayesian networks, hierarchical task networks, neural networks, complex interconnected influence relationships, etc. More information about these approaches is discussed in MSG-198 report [3]. The **Perceivable Behaviour** component provides an explicit representation of the behaviour of the self-agent, i.e. the observable or detectable actions carried out by the self-agent. Perceivable behaviour may be intentional physical activities, such as firing or running, automatic physical responses such as a startle response, or even perceivable emotional reactions such as crying out in anguish. Table 1 provides a summary of these model components for quick reference.

Table 1: Main Components of the ABRM.

Model Component	Description
The State of Self (SoS)	Represents the set of state variables describing the self-agent.
State of World (SoW)	Represents the set of state variables describing the world which comprises the environment and all other agents and entities in the model.
Agent Information Processing	Represents the internal processing of the self-agent, taking in Self Information and World Information, and producing a Response.
Perceivable Behaviour	Provides an explicit representation of the self-agent's response behaviour.

The ABRM has four main effects arcs connecting the model components. These effects arcs represent the ways in which the arc's origin model component changes either the SoS state variables or the SoW state variables. The effects modelled on these arcs may represent both kinetic and non-kinetic effects. The names of these arcs are listed in Table 2 along with a brief description of each. Each effect arc name is self-explanatory, listing first the origin model component and then the destination.

Table 2: ABRM Effects Arcs.

Effect Arc	Description
Effects of Internal Processing on State of Self	Represents all the effects that the self-agent's internal information processing has on the State of Self state variables; these effects are entirely internal and therefore not perceivable by any other agent or entity in the model.
Effects of own Behaviour on State of Self	Represents all the effects that the behaviour of the self-agent has on itself, on its own state variables.
Effects of own Behaviour on State of World	Represents all the effects that the behaviour of the self-agent has on anything else in the model outside of itself.
Effects of State of World on State of Self	Represents all the effects that anything else in the model outside of the self-agent has on the self-agent's state variables.

Figure 1 presents the full diagram of the structure of the ABRM. The model components from Table 1 are shown as rectangles, and the effects arcs described in Table 2 are shown as solid-line arrows. There is one additional 'hidden' effects arc in the ABRM, represented by the circular arrow inside the State of World component. This represents all the effects that anything in the model (outside of the Self-Agent) has on anything else in the model (other than the Self-Agent). In addition, as can be seen in Figure 1, there are three additional arcs shown as dashed-line arrows; these are the information arcs that represent the passing of information from one model component to another: World Information, Self-Information, and Response. Note that the World Information arc passes to the Agent Information Processing component only those aspects of the State of World that are knowable to the Self-Agent.

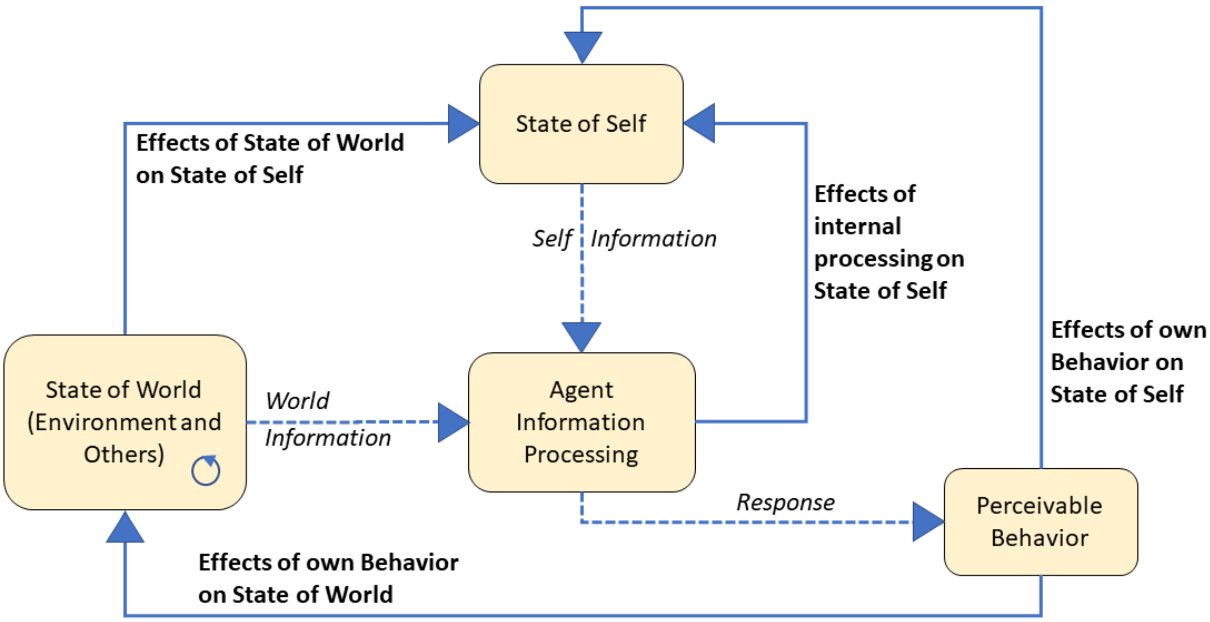

Figure 1: Agent Behaviour Reference Model (ABRM) [3].

It is important to note that the ABRM is not designed to facilitate the documentation of an entire constructive simulation model. Rather, it facilitates the documentation and communication of how human behaviour (for a single agent) is conceptually represented in a simulation model. It also does not directly address technical approaches of computer model composition.

3.0 APPLICATIONS OF THE ABRM

This section illustrates the application of the ABRM, exemplifying how two distinctly different human behaviour simulations models can be described as ABMs with a common structure that can be more easily discussed by researchers across disciplines and nations. These example ABMs demonstrate how each part of the ABRM is used to elucidate important aspects of the human behaviour representation. The ABRM provides all the essential structural elements for conceptually representing human behaviour models for constructive simulations.

Constructive simulations representing human behaviours are generally constructed for two broad purposes, Analysis and Training [3]. Analytical simulations are used to explore new concepts and capabilities, and may be used to aid decision making and identify factors which give rise to behavioural complexity. To achieve this, analytical models seek to represent human behaviour at a higher level of detail and complexity, often incorporating many different behavioural factors, and therefore many different behavioural responses may emerge from any given scenario resulting in what's termed 'emergent behaviour'. Experiments are typically conducted with these simulation models, systematically varying different factors and analysing the results to provide insights. Analytical simulations often contain stochastic elements, in which case many runs with different random numbers are conducted for each combination of factor settings.

Training and education simulations require more predictability and control over scenarios delivered to a training audience, and therefore tend to model human behaviour with less complexity, representing fewer behavioural factors and often minimising random elements. Such simulations result in a limited, pre-set number of potential behavioural responses, which are often described as 'pre-scripted'. In a training context, fully realistic behaviours are not required and may also be counterproductive, although simulations do need to be sufficiently realistic to provide an immersive learning experience. The key requirement for training simulations is to provide some degree of variability in behavioural complexity that can be adjusted for the training need but is also intentionally limited to avoid emergent behaviours which may undermine the goals of the training scenario. Outcomes of training simulations should be largely predictable to the instructors to ensure that training objectives are met and are understandable to the training audience to aid learning.

Section 3.1 describes a simulation model used for training in the UK, where the self-agent represents an aggregated group of people. Section 3.2 then describes a more complex analytical simulation model from the US, where the self-agent represents an individual and insights from complex interactions are sought.

3.1 IICM

The Influence and Infrastructure Combat Model (IICM) is an agent-based, hybrid warfare simulation, used to explore and demonstrate the impact of influence operations on a human terrain. It can be used as a sandbox environment in a training and education context, and as an analysis tool. From the onset, it was designed to work with highly approximated datasets such as those generated from national census records or other publicly available material. The design of the IICM assumes that face-to-face interactions play a dominant part in communication, and so influences long term behavioural change.

The underlying model includes representation of geography, the human population, cultural groups, critical infrastructure, and an abstracted representation of the information flows that allow societies to function. The model is designed to respond to information operations, physical activity, cyber and environmental disruption.

Geographical terrain is split into ‘zones of control’ typically representing a city block or a small geographical region. A typical scenario will use 10-20 zones, often a mixture of urban, peri-urban and rural areas. The human population is subdivided into small packets of people called “population groups” (PG), each typically representing 5-50 people. The people making up a PG share a similar age, gender, and a collective identity (faction). A typical simulation will have hundreds to thousands of different PGs.

Factions represent the groups competing for popular support within the human terrain, each vying for narrative dominance. PGs do not change membership of a faction, however their support for each faction (including their own) alters as the simulation progresses. Each pair of factions has an associated cultural distance[1] which describes how closely a faction member’s world view aligns with members of other factions.

PG agents move according to a daily cycle between a home location and work location, where they may interact with each other. Transport networks such as roads and railways facilitate the movement of PGs between zones. Other infrastructure networks, e.g. power and telecoms, mediate communications and permit the functioning of social media and broadcast media, e.g. television or radio.

Information is modelled as discrete packets of sentiment called messages, each capable of altering the recipient’s perception of the world and other factions. Messages are passed between PGs as they interact on a person-to-person basis, representing face-to-face communication, or may be introduced to many PGs at the same time, representing the effects of broadcast or social media. Messages may also be applied to agents in a specific geographical area to represent them observing an impactful event. The chance of a message being communicated between two PGs is based on their age difference and cultural group, and the chance of a message being correctly understood (interpreted) is based on the cultural ‘distance’ between the sender and

[1] Current iterations of the model use Hofstede’s Cultural Dimensions Theory [10] to describe how members of a faction perceive six core values such as hierarchy, gender differences and individualism. The greater the difference between the cultures, the harder they will find it to successfully communicate complex concepts, and the greater the chance that the meaning of a message will become distorted.

the receiver. As they are received, messages may be misunderstood and corrupted, changing the underlying sentiment and so giving rise to false rumours and speculation.

For IICM, the velocity and veracity of messages are the primary factors under investigation, with the agents providing the environment through which the messages move, live, and die. The simulation allows the user to view the propagation of information through the human terrain over time and shows how it can be channelled through different subgroups by targeting influence operations. Figure 2 depicts how IICM may be decomposed into the ABRM conceptual framework. A full overview of IICM can be found in Robson (2019) [11].

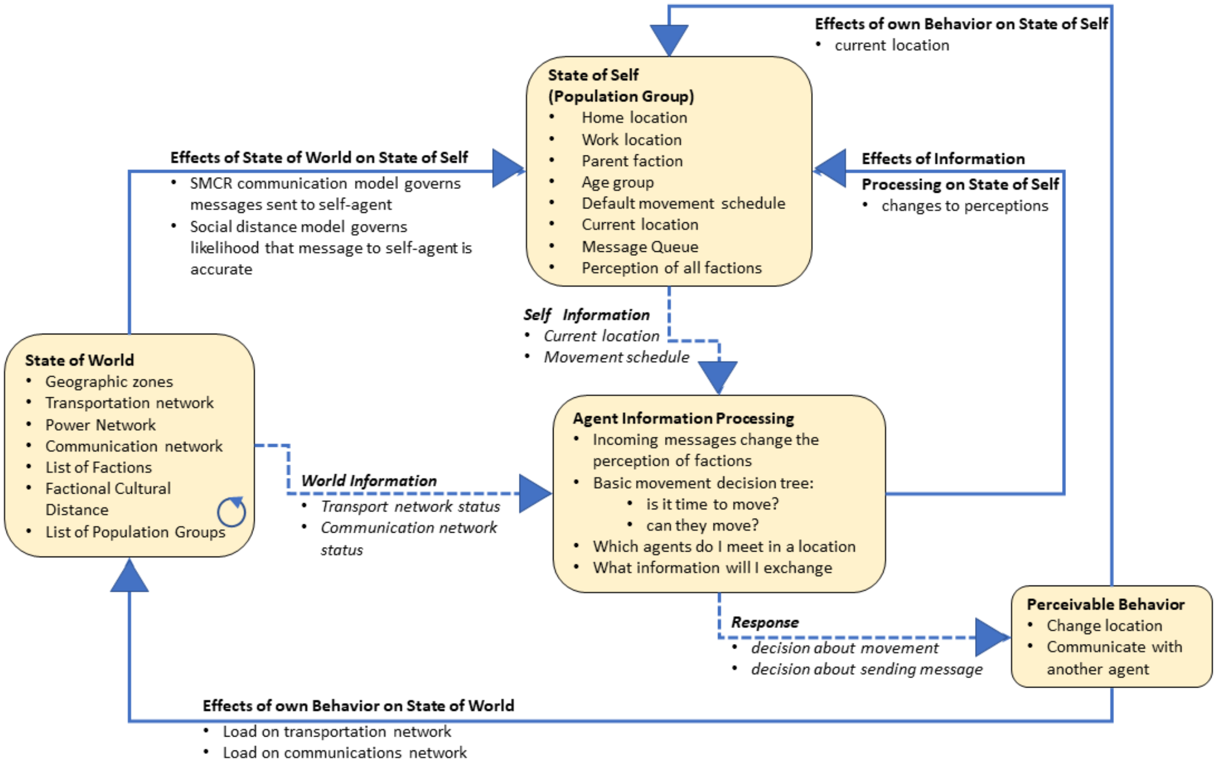

Figure 2: IICM based Agent Based Model

State of Self is used to hold the information pertaining to the individual Agents, one per PG. Home Location, Work Location, Parent Faction, Age and Schedule are static factors which do not change in a simulation run. Current location stores the geographic location and can be either be a specific geographic zone or moving along a transport link. The message queue is a list of all information about the world held by the agent and grows as the simulation progresses. Lastly, an agent tracks its support for all factions within the model, including its own.

Agents perform rudimentary **Agent Information Processing**. Agents change location based on internal needs, which is represented by a daily schedule. They will choose a suitable mode of transport based on available transport networks and move between a home zone and a work zone; the latter representing places where people meet including schools, shops, and entertainment as well as formal places of employment. When agents gather in a zone there is a chance that they will communicate with each other; the probability of which is based on factors such as culture, age, and gender. When two PGs communicate, a small number of messages will be exchanged using a modified Sender-Message-Channel-Receiver (SMCR) communication model[2] [12]. Message priority is based on how old the information is (older messages are regarded as less significant than new messages), and how exciting it is (messages that have a large sentiment shift are given priority over mundane information). Received messages are stored in a list and evaluated against pre-existing information. Some messages adjust the self-perception of factions (some information is "believed"), whilst other messages are ignored (but still retained). All messages that have been stored may be exchanged, including messages which have not been believed (e.g. gossip).

In this system, PGs only have two **Perceivable Behaviours**. They move between locations, depending on schedule and available transport links, and they communicate with each other. All other actions apply to State of Self.

State of World is used to describe the environment in which the agent operates. This includes geographical factors such as location zones and transport networks, the communication networks that allow information to be exchanged, and infrastructure networks such as power and water. It also holds a list of all active agents within the simulation, and the factions which they belong to.

3.2 WRENCH

In this section we introduce the Workbench for refining Rules of Engagement against Crowd Hostiles (WRENCH), a complex simulation model that represents civil security activities for the purpose of generating insights for decision support. We then demonstrate through a simplified example how the ABRM structure can be used to describe how an agent's behaviour is modelled for this type of simulation model.

The WRENCH simulation model was developed to gain insights into crowd behaviour, and has been customized to model civil support activities where a security force (SF) interacts with a potentially hostile crowd using intermediate force capabilities (IFCs) to manage any emerging hostilities. WRENCH explicitly models security force members, squads, command, civilian individuals, and civilian groups within a crowd. The WRENCH simulation model represents these agents and interactions at a high level of complexity in order to more realistically represent the complexities of real human behaviour and decision-making. WRENCH can be used in two ways. It can be used interactively, where the user can change aspects of the simulation as it runs via a graphical user interface (GUI) and watch the results play out in the animation to gain insights experientially. It can also be used constructively, running large-scale experiments to test the potential effects of different security force characteristics and choices under a variety of and circumstances on markedly different populations. A full overview of WRENCH can be found in Aros et al [13], and a full experiment and results using WRENCH can be found in Aros and McDonald [14].

Within WRENCH, a civilian individual is modelled with two agents: a Person agent (physical aspects) and an Identity agent (emotional, cognitive, social aspects) with a large number of state variables and complex math and logic functions. To simplify this example we will use as the Self-Agent a Whole Person (WP) agent (physical and cognitive aspects combined), include a small portion of the state variables and logic, and reduce the complexity of some aspects of WRENCH in the example ABM. Figure 3 depicts the ABM for WP agents in WRENCH, using the ABRM structure. In the remainder of this section we will describe this general ABM by taking a walk-through of a single simulated cycle assuming specific variable values for one instance of a WP agent. Figure 3 provides the graphic for this example.

[2] SMCR is a simple linear transmission model first proposed by David Berlo in 1960 [12]. By avoiding concepts such as feedback loops, it allows IICM to view information flow as a set of 'atomic' messages, subject to evolutionary pressure.

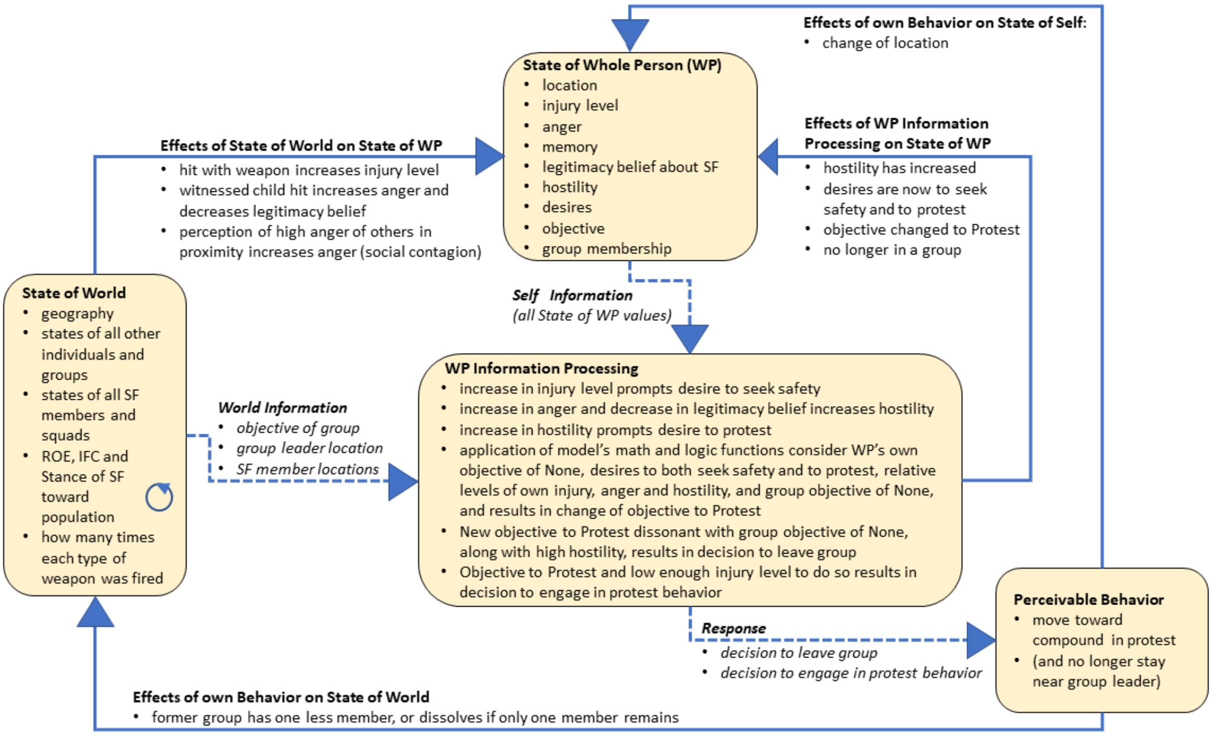

Figure 3. ABRM structure with WRENCH Whole Person (WP) agent example.

To walk through this ABM example we begin with the **State of World** ABM component at the left side of the diagram. This consists of every state variable in the simulation model outside of the WP self-agent such as the geography of the scenario, states of all other individuals and groups, the states of all SF members and squads, the *ROE*, *IFC* and *Stance* of the SF toward the population, and data tracking such as how many times each type of weapon was fired.

The arc going from **State of World** to **State of WP** represents all the effects of the former on the later. So the **Effects of State of World on State of WP** includes all of the specific effects, essentially the transition functions or logic, that the **State of World** state variables have on the **State of WP** state variables. In WRENCH this includes immediate physical and emotional responses such as: if the WP is hit with an injury-inducing weapon the WP's *injury level* increases; if WP witnesses a child being hit by a weapon then WP's *anger* increases; and if the *anger* level of others in proximity is somewhat higher than WP's *anger* level then WP's *anger* level increases (representing emotional contagion). The experienced and witnessed hits are also stored in WP's *memory*. This effects arc also demonstrates that the ABRM structure can represent kinetic effects (weapon hit causing injury), non-kinetic effects arising from kinetic events (witnessing a hit causing increased anger), and entirely non-kinetic effects (emotional contagion).

The **State of WP** includes all the state variables that describe a WP agent and their current values. Some of these WP state variables in WRENCH are: physical *location*, *injury level*, *anger*, *legitimacy belief* about SF, *memory*, *hostility*, *desires*, *objective*, and *group membership*. To proceed with this example we will assume that WP's *injury level* was just increased from "none" to "low" from the effect just described, and similarly its *anger* increased from "moderate" to "high". We'll also assume that WP has "low" hostility, moderate level of *legitimacy belief* about the SF, no particular desires, an objective of None (representing no particular objective), and is in a group.

There are two arcs going into the **WP Information Processing** model component: **Self Information** and **World Information.** The **Self Information** arc represents the passing of WP's state variable values information. The **World Information** arc represents the passing of all World state variable values that are knowable by WP such as *objective of group* (assumed to be "None" for this example), *group leader location*, and *SF member locations*.

The **WP Information Processing** model component contains all the WP agent's math and logic functions that model its cognitive processing, taking in the aforementioned state variables values and producing the response of WP. For WRENCH the **WP Information Processing** begins with initial cognitive reactions to the aforementioned changes to WP's state variables. The most recent events in memory decrease WP's *legitimacy belief* about SF, and WP's increased *anger* and decreased *legitimacy belief* thereby increase its *hostility*. WP's desires can also change. Here the increase in *injury level* prompts a *desire* to "seek safety", and the increase in *hostility* prompts a *desire* to "protest". At this point WP has two conflicting internal *desires* ("seek safety" and "protest") and an *objective* of "None". The model logic takes this information, along with the group's *objective* of "None" and the relative values of the other aforementioned state variable values and determines that WP's new *objective* is to "Protest". This new *objective*, along with a low-enough *injury level* to do so, results in WP's decision to engage in protest behaviour. However, WP's new "Protest" *objective* is dissonant with the group *objective* of "None". Here the model logic takes into consideration levels of other WP state variable values and results in WP's decision to leave the group to resolve this dissonance.

There are two outputs from the **WP Information Processing** component. The **Response** arc represents the passing of WP's behavioural decisions to the **Perceivable Behaviour** model component. The **Effects of WP Information Processing on the State of WP** arc explicitly shows the effects that the **WP Information Processing** had on the **State of WP** (WP's state variable values) mentioned above that are not externally perceivable.

The **Perceivable Behaviour**: model component represents the acting out of the behavioural decisions. In this case WP will move toward compound in protest. There is an additional behavioural change as well: since they are no longer in a group they will no longer be staying within a specified distance from the group leader.

There are two types of effects coming out of WP's **Perceivable Behaviour**. The **Effects of own Behaviour on State of Self** are the perceivable effects on WP as a result of its own behaviour such as the change of location. The **Effects of own Behaviour on State of World** include effects such as WP's former group having one less member (or, if only one member remained, the group would dissolve). That completes the example cycle through the ABM.

The documented ABM is the model of the variables, rules and relationships that define the specific WP type (class) of agent in WRENCH. When the simulation model is coded and run, a separate ABM instance is created for each WP agent in the model. In WRENCH there also several other types of agents, so full documentation would include an ABM for each type of agent. This example demonstrates that, even for very complex models, the ABRM can be used to standardize the presentation of the ABM design for each type of agent.

4.0 CONCLUSION

The ABRM was developed through the collaboration of MSG-198 members, who came from different nations and different professional disciplines to establish a common framework detailing the key components involved in modelling human behaviour. The ABRM is intentionally agnostic, not detailing specifics about the context and model, such as what state variables are included in a model of the self and the world, what logic or methods comprise the internal information processing, and exactly how effects are applied. Being a general reference model, the ABRM provides the broad categories of model aspects, specifying the structure that any model-specific ABM would take.

The value and purpose of the ABRM is to enable future multi-nation and interdisciplinary collaboration and discussion about the representation of human behaviour in simulation modelling by providing a common language and understanding. Use of the ABRM will allow both, the approaches to modelling, and specific models, to be compared and contrasted more easily, and by facilitating multi-nation and interdisciplinary discussion, the ABRM promotes an opportunity to create a greater understanding of human behaviour modelling by enabling the co-construction of knowledge through diverse collaboration.

The common understanding, provided by the ABRM, better facilitates follow-on conversations about composition and reuse of human behaviour model components. For more information on composition, reuse and data sources see the NATO MSG-198 report [3].

Whilst there is clear value in using the ABRM, it is important to emphasise that a single ABM may not document the full scope of a simulation model, particularly when there are other types and classes in the simulation model. To document the entire scope of a simulation model, each agent type or class must have its own ABM, and some additional documentation about the environment may be desired. Furthermore, it is important to note that the ABRM is designed for documenting the conceptual design of a simulation model, not for documenting the computer code design and structure.

This paper demonstrates the application of the ABRM for two different simulation models. As the ABRM becomes more established and used, the suitability of the ABRM for describing human behaviour representation in a broader variety of models will be further demonstrated. Succeeding the MSG-198 Specialist Team, a follow-on Task Group MSG-222 “Representing Human Behaviour and Decision-making in Modelling and Simulation” has been established. This is due to begin in November 2023 and work will be conducted over three years. Some of the initial goals of MSG-222 include the evaluation and expansion of the ABRM. This will include ABMs for different Use Cases, involving different types of agents (e.g. Military forces, civilian populations etc.), different types of behaviours and effects on behaviour, and different types of conflicts and kinds of weapons (including kinetic and non-kinetic, lethal and non-lethal weapons).

REFERENCES

[1] UK Ministry of Defence. (2015). *Future Operating Environment 2035*. London: Ministry of Defence.

[2] North Atlantic Treaty Organisation (NATO). (2012). *NATO Modelling and Simulation Master Plan.* Edition 2. AC/323/NMSG(2012)-015. NATO.

[3] North Atlantic Treaty Organization (NATO). (2023). *Composable Human Behaviour Representation in Constructive Simulation Systems*. Science and Technology Organization Technical Report STO-TR-MSG-198. NATO.

[4] Rymill, S.J. (2008). *Psychologically-based simulation of human behaviour* (No. UCAM-CL-TR-717). University of Cambridge, Computer Laboratory.

[5] Carlile, P.R. (2002). A pragmatic view of knowledge and boundaries: Boundary objects in new product development. Organization science, 13(4), pp.442-455.

[6] Kotlarsky, J., van den Hooff, B. and Houtman, L. (2015). Are we on the same page? Knowledge boundaries and transactive memory system development in cross-functional teams. Communication research, 42(3), pp.319-344.

[7] Cronin, M.A. and Weingart, L.R. (2007). Representational gaps, information processing, and conflict in functionally diverse teams. Academy of management review, 32(3), pp.761-773.

[8] Fischer, G. (2001). Communities of interest: Learning through the interaction of multiple knowledge systems. In Proceedings of the 24th IRIS Conference (Vol. 1, pp. 1-13). Department of Information Science, Bergen.

[9] Merriam-Webster Dictionary. (n.d.). In Merriam-Webster.com. Retrieved from https://www.merriam-webster.com/

[10] Hofstede, G., Hofstede, G. J. and Minkov, M. (2020). *Cultures and organizations: Software for the mind*. McGraw-Hill.

[11] Robson, D. (2019). *Influence and Infrastructure Combat Model (IICM) Final Report* (NSC-0781.004-046). Defence Science and Technology Laboratory.

[12] Berlo, D.K. (1960). *Communication: An introduction to theory and practice*. New York, NY: Bolt, Rinehart, and Winston.

[13] Aros, S. K., Baylouny, A. M., Gibbons, D. E., & McDonald, M. (2021). *Toward better management of potentially hostile crowds.* Proceedings of the Winter Simulation Conference (WSC). IEEE.

[14] Aros, S. K. & McDonald M. (2023). *Simulating Civil Security Activities in Stability Operations.* Forthcoming in Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC).