Instructional Environments - Characterising Training Requirements and Solutions to Maintain the Edge

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ABSTRACT

With the ever increasing complexity of warfighting systems in the Network Centric Warfare era, and the changing nature of the threats we face exemplified by the emergence of asymmetric warfare, maintaining the edge and achieving force transformation is ever more challenging. One of the many aspects of this challenge is ensuring that we identify the most appropriate training solutions for our warfighters. Current models provide guidance at the lower levels of individual training episodes but are found wanting in critical areas such as collective training and when trying to inform choices and make business cases when developing new capabilities. To address this problem we are developing a comprehensive and rigorous model of instructional environments, instructional methods and the nature of training tasks themselves in order to elicit a rigorous yet accessible method for identifying training solutions which meet the key characteristics of the demanding training problems that we face, whatever their scale. This paper reports on the outcome of the first stage of this work, which is the development of a comprehensive and robust model of the instructional environment. The model embraces actors, communication modes and channels, methods of encoding of stimuli and responses and the characterisation of key resources used in the instructional process. It forms the foundation for the characterisation of instructional methods and media, essential for the determination of key correspondences to the requirements of training problems which have to be supported if force transformation is to be achieved.

ABOUT THE AUTHORS

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INTRODUCTION

Background

With the ever increasing complexity of warfighting systems in the Network Centric Warfare era, and the changing nature of the threats we face exemplified by the emergence of asymmetric warfare, maintaining the edge and achieving force transformation is ever more challenging. One of the many aspects of this challenge is ensuring that we identify the most appropriate training solutions for our warfighters.

The UK Ministry of Defence (MoD) has identified a number of key issues related to training associated with the acquisition of new capabilities. Firstly, when whole life costs are examined, training accounts for a substantial proportion of those costs. Therefore, there is a significant financial imperative to select the most cost effective training solution possible. Secondly, in the MoD's current acquisition system, much of the work that is done to identify the optimal training solution is undertaken downstream of the key funding decisions. In the initial concept and assessment phases of developing a new capability, alternative concepts for the provision of the required capability are explored. Once an appropriate option has been identified, a costed business case is developed for this option. It is at this point that indicative training costs should be developed and assessed. However, it is only during the subsequent demonstration and manufacture stages that the Training Needs Analysis (TNA) process is conducted to identify the optimal training solution. In the final stage of TNA training options analysis is conducted during which alternative, costed options are evaluated. We are therefore in a 'chicken and egg' situation. The solution to this is to bring forward part of the TNA process and design it in such a way that it enables us to characterise and cost, putative training solutions while remaining at a fairly high level of abstraction.

Early Training Needs Analysis

Having stated the problem and determined that we need to commence TNA earlier, we need to determine how this can be achieved in a way that generates satisfactory output, from what is known at that stage in the procurement process, and without exhaustive amounts of effort. The challenge is to identify a way of characterising training tasks and potential training solutions, whilst working at a relatively high level of abstraction in terms of the capability that is to be developed, such that whole life costs of the training component of a potential capability solution can be estimated.

Alternative training solutions are often characterised in terms of the instructional methods and media that are used in their delivery. These terms can lack precision. For example, e-learning can be described as both an instructional medium and a method, as can simulation (Romiszowski, 1988). Gagne, Wager, Golas and Keller (2005) distinguish between instructional media, instructional delivery methods and instructional delivery strategies. In their system a full fidelity simulator is categorised as an instructional delivery method which is identified as supporting four delivery strategies (collaborative learning, demonstration, simulation and practice) and is related to the instructional media type of 3D animation. So simulation is classified as both an instructional delivery method and a delivery strategy but not a medium.

Notwithstanding this potential confusion, there are a variety of models which have been developed to guide choices in training options under the banner of media selection models. Many were developed in the 1970s and have become outdated simply because they do not cater for the range of technologies currently available. Perhaps the most comprehensive model that has current utility is that put forward by Romiszowski (1988). However, the start point for this model is the definition of behavioural objectives for each topic to be taught. Also, the model focuses on micro level decisions about the choice of media to support individual instructional events within lessons. In the absence of a suitable extant model, a new approach needs to be developed.

There is a wide range of factors to be considered in selecting an appropriate training solution. These include but are not limited to the nature of the training task, learner characteristics, costs, resource and infrastructure requirements, policy constraints and instructional management (Huddlestone and Pike, 2005, 2006b). The issue is where to start in the analysis.

Romiszowski (1988) highlights a key feature of the instructional process when he characterises instruction as a two-way communication process - involving stimulus, internal processing by the recipient and response. Instructional media can then be characterised as all of those components that mediate communication (i.e. capture and then transmit stimuli) between instructor and student. The totality of the instructional media, training resources, communications channels, instructors and students we term the Instructional Environment.

The approach which we are taking to develop a suitable methodology for identifying training options is based on three primary considerations:

Firstly, how do students interact with systems (and each other) during the instructional process for a given training task and how can we characterise these interactions in a simple but meaningful way?

Secondly, how can these interactions and their attributes be mapped into the instructional environment?

Thirdly, how can instructional methods be overlaid, or characterised within this environment?

This paper reports on the outcome of the first stage of this work, which is the development of a comprehensive and robust model of the instructional environment. After a brief discussion of the nature of training tasks from an information processing perspective, the proposed instructional environment model is described in detail.

TRAINING TASK MODEL

Figure 1 outlines a training task modelled in information processing terms. The training task model is a model for describing the key elements or attributes of the training task from the perspective of how they impact on design of instructional solutions.

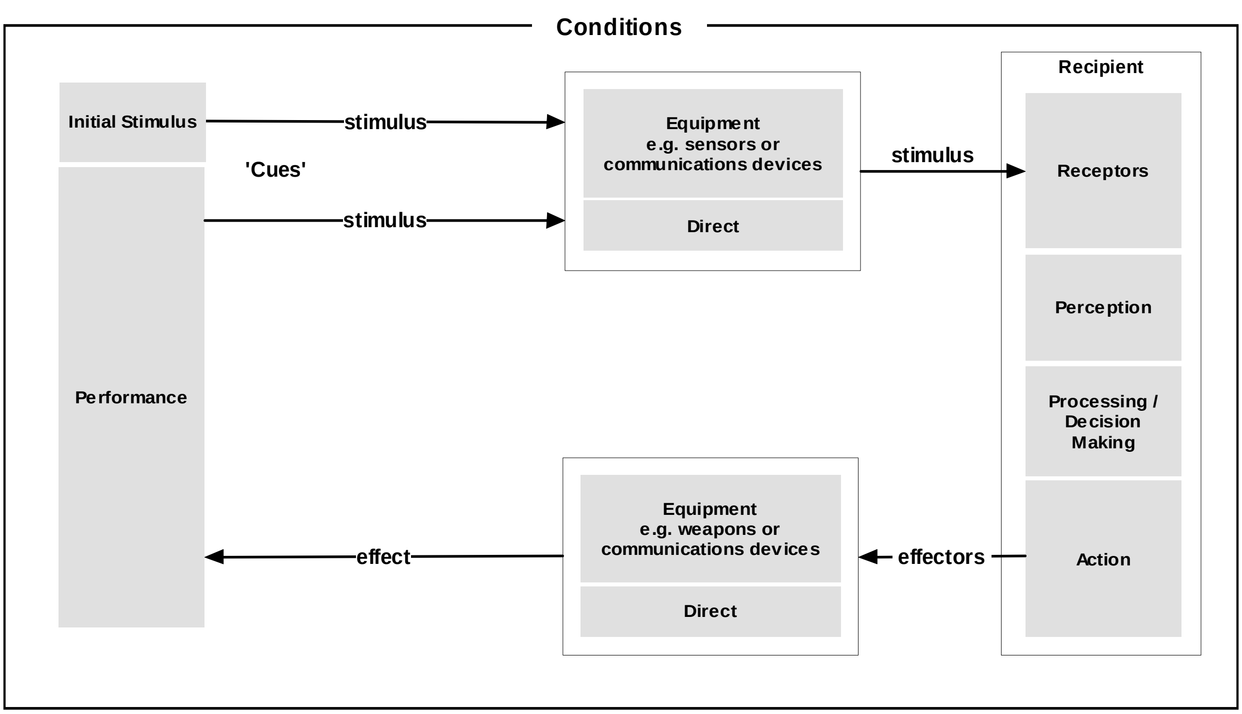

Figure 1. Information Processing Model of a Training Task

This enables us to characterise the training task in a way that is directly meaningful to training options analysis, while remaining at a broad level of abstraction.

In outline, a recipient receives stimuli (cues) either directly from the outside world, or through equipment (for example a radar display or a radio). The recipient receives stimuli through a set of receptors (eyes, ears) and then performs some mental processing (such as decision making) on the received stimuli which may result in action. The recipient generates action through a set of effectors (the muscles of the body) which may deliver an effect directly (such as speech) or may be captured and transformed by equipment into another effect (such pressing the 'transmit' button on a radio or pulling the trigger on a weapon). This effect is transmitted and will generate a result, the quality or performance of which, may be satisfactory or otherwise (e.g. hitting the target or missing it). Observing performance effects (i.e. stimulus feedback from the effect) may lead to renewed action, or a change to a new type of action (such as 'do nothing').

Stimulus Attributes

Stimuli can be characterised in terms of stimulus types corresponding to the senses that receives the information. The senses are characterised as:

Stimulus	Sense Organ
• Visual	Eyes
• Auditory	Ears
• Haptic	Skin /Touch
• Gustatory (Taste)	Tongue
• Olfactory (Smell)	Nasal lining
• Vestibular (perception of acceleration, orientation, balance)	Semi-circular canals of the Inner Ear
• Kinaesthesia (perception of movement and orientation of the limbs)	Muscles/Tendons/ Joints

The first 5 senses are the most familiar to us, however added to the senses that receives external stimuli; we have two senses that provide information on orientation and acceleration of the body. The sense of balance or equilibrium (the vestibular sense) is generated within the semi-circular canals of the middle ear which enables us to perceive acceleration, and orientation of the body and enables us to keep our balance. Kinaesthesia is the sense that describes the position of the body and the orientation of the limbs through stretch sensors in the muscles, tendons and joints (Blake & Sekuler, 2006).

For any training task there are a set of cues or types of stimulus that are required – for example:

1) Firing a personal weapon – observation of the target requires a visual stimulus, secondary cues related to system function may be visual, auditory (i.e. hearing the weapon firing or hearing only a click), or kinaesthetic (such as recoil).

2) Solving an algebraic problem – visual stimulus enables the reading of the symbols, while in writing the visual sense provides feedback as to placement of symbols, neatness and legibility.

3) Manual flying of an aircraft – the pilot is taking in visual, auditory and haptic cues and is also receiving vestibular and kinaesthetic stimuli.

Response Attributes

When we have chosen to respond to a stimulus (i.e. act) within the context of a learning task there are a set of muscles (effectors) which we operate to generate a set of outputs, this may range from speaking a single word, to pulling the joystick of the aircraft back and pushing 2 buttons simultaneously. No list or taxonomy exists for the types of reactions that can be generated by a human being, and this is further complicated by the fact that multiple responses can be executed simultaneously. However one can describe the set of required effectors to execute the task at hand. From the examples above the effector (response) attributes required are:

1) Firing a personal weapon – muscles to hold the weapon, control of wrist, hand, fingers, postural muscles.

2) Solving an algebraic problem – effectors to control writing instrument or keyboard.

3) Manual flying of an aircraft – effectors to control feet, arms, hands, fingers and head position in order to manipulate the flying controls whilst observing the external scene and internal displays.

Benefits of the information processing view

Taking an information processing view of training tasks has a significant benefit in that, as soon as the concept for the design of a capability is developed to the point where the role of human operators is outlined, we can start to make assertions about the nature of the interactions that they are likely to have with equipment and other operators.

If we consider the provision of a capability for long range, airborne reconnaissance, two potential options are an Unmanned Aerial Vehicle (UAV) or a piloted aircraft. A UAV operator will have to learn how to control and manoeuvre the UAV using controls on a workstation in response to information provided on a set of displays. The aircraft pilot by contrast is immersed in the aerial environment, though many cues (stimuli) are mediated through the interfaces present in the cockpit (such as Multi-function Displays, captions within the Heads Up Display). By considering how the operator has to interact with each system we can make some assertions about the potential training solutions. In both cases above, simulation may well provide a significant element of training provision for operators by replicating their respective operating environments. However, the requirements for these simulations would be significantly different. The key lies in determining how the individual has to interact with the system, in other words we must characterise the nature of the stimuli (cues) they receive and the nature of the responses they have to make.

INSTRUCTIONAL ENVIRONMENT MODEL

Once we have stated a set of training tasks in performance stimulus–response terms we can look at the instructional environment, and consider what properties it needs to support in order to deliver instruction appropriate for the learning task. Figure 2 shows a simple model of the instructional environment first outlined in Huddlestone and Pike (2006b).

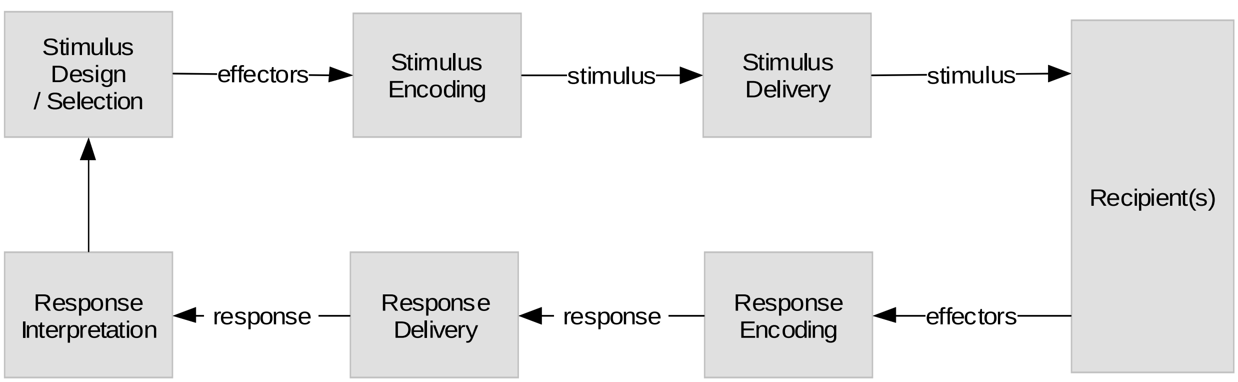

Figure 2. A Simple Model of the Instructional Environment

In the simple model of the instructional environment we have 7 key areas:

1) **Stimulus design / selection** – the stage where the instructional messages to be carried are designed or selected by the instructor or instructional system.

2) **Stimulus Encoding** – the stage where instructional messages are encoded, or captured.

3) **Stimulus Delivery** – the stage at which instructional messages are delivered or broadcast to the recipient.

4) **Recipient** – the stage where recipients (i.e. students) receive the instructional stimuli and then generate (through effectors) responses.

5) **Response Encoding** – the stage where student responses are captured and then transmitted.

6) **Response delivery** – the stage where student responses is transmitted, normally to the instructor or examiner.

7) **Response interpretation** – the stage where student response is compared to the reference standards and a decision or judgement about the

quality of the response is made. This may then initiate another processing cycle.

To make the abstract concepts described in the model more concrete it is useful to apply the model to a simple classroom teaching situation. For example, consider the situation where an instructor in a classroom asks a question in class that requires a student to write the answer on the classroom whiteboard. A model of the instructional environment for this situation is shown in Figure 3.

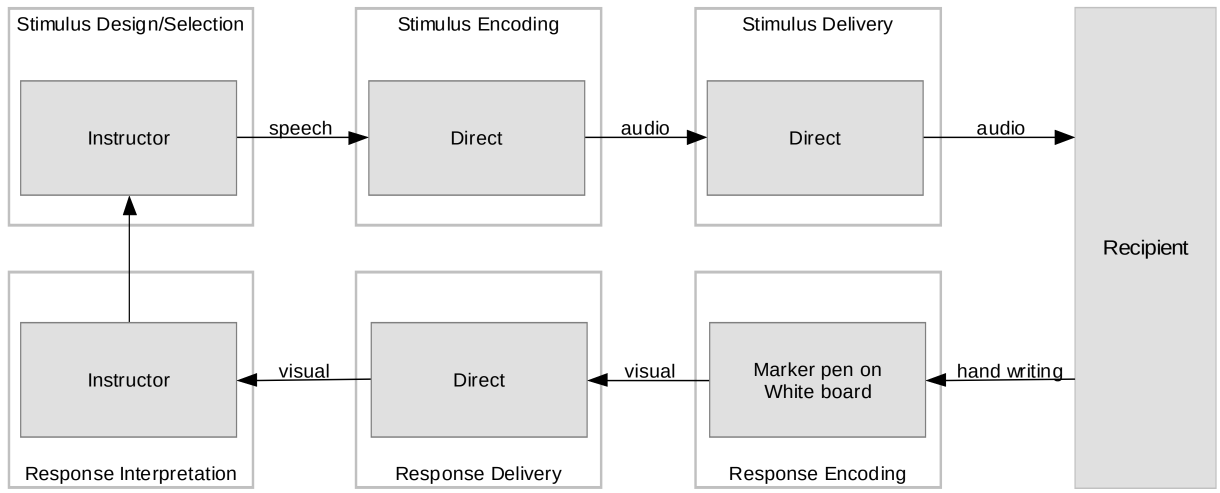

Figure 3. Instructional Environment for a Simple Classroom Example

1) **Stimulus design** – the instructor decides which topic and question to ask, for example: "Draw a basic map of France indicating the 5 major cities and 3 major rivers".

2) **Stimulus encoding** – the instructor asks the question by speaking aloud.

3) **Stimulus delivery** – in this case this is direct (i.e. sound waves are propagated through the air), in many cases this may be intermediated by technology such as radio, telephone or internet.

4) **Recipient (Student)** – hears the instructor's question, thinks, and then responds to the question.

5) **Response Encoding –** here the student responds to the question by drawing on the white board using a marker pen.

6) **Response Delivery** – the response is directly delivered to the instructor as both student and instructor are co-located in the same room.

7) **Response Interpretation** – Here the instructor reflects on the student answer and then selects how to react.

In terms of the basics of this operation we could deliver the question to the student via the telephone system, or even via video conference. In these examples the instructor voice would be encoded through technology, and then delivered through an appropriate transmission and delivery technology. In both of these examples we are encoding and delivering auditory stimulus. Similarly, the student could capture the result in a drawing package on a computer and email the digital file to the instructor. In this case we have modified both the response encoding and the response delivery mechanisms, though the instructor will still evaluate the results through visual cues. A version of the instructional environment capturing these options is shown in Figure 4.

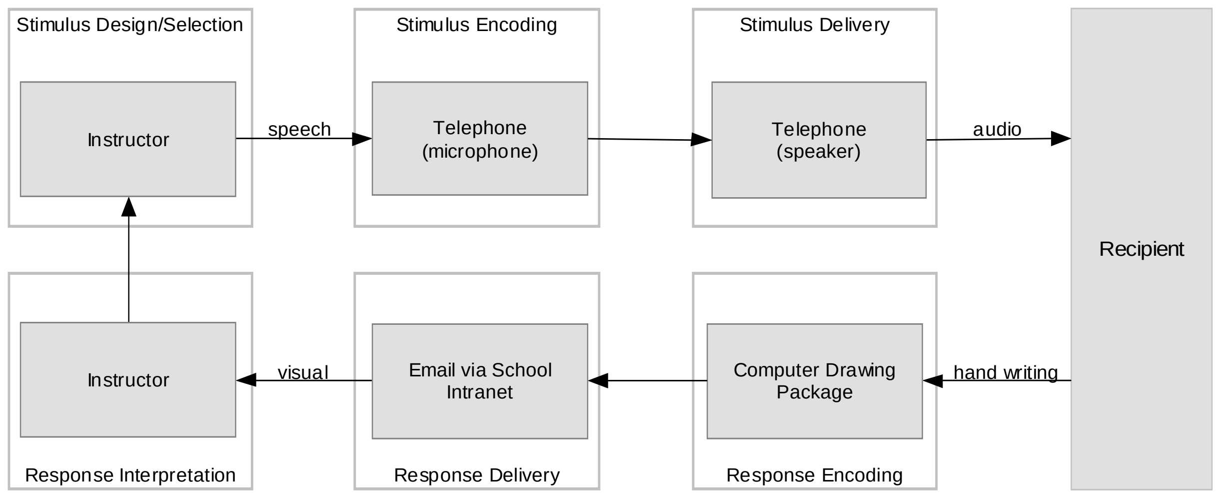

Figure 4. Instructional Environment for a Communications Technology Example

The whole instructional environment can be considerably more complicated, but in essence, all of the 7 key areas in the diagram have to either be satisfied (i.e. something must exist to occupy the 7 compartments of the model), or conveyed in a direct manner ('direct' is only a potential option in the areas of stimulus encoding, stimulus delivery, response encoding and response delivery).

The key types of *instructional resource* available to us in the various parts of the instructional environment are:

1. **Stimulus Design**
   - **The instructional facilitator (instructor)**, or in future, the AI in an Intelligent Tutoring System (ITS) which is selecting appropriate instructional messages to convey to the student.
   - **Auto-instructional materials** (such as e-learning).

2. **Stimulus Encoding**
   - **Instructional Aids**, instructional media used under the control of an instructor or ITS.
   - **Learning Resources**, instructional media used under the control of the student.
   - **Training Resources**, resources used by the instructor for demonstration – examples might include a real rock face or climbing wall in the case of teaching rock climbing, or a personal weapon when teaching skills relating to that weapon such as stripping and cleaning or shooting. It should be noted that demonstration of training resources (for example the procedure for stripping a rifle, could be videoed and then used as instructional aid or learning resource. Complex simulacra of real systems or environments (i.e. simulations) would be categorised as training resources, as would their 'real live' counterparts.
   - **Auto-instructional materials**, interactive media used under the control of the user, such as a work book, or piece of e-learning.

3. **Stimulus Delivery**
   - **Direct**, in this case encoded stimuli is delivered direct to the user without intermediation (such as the case of reading a book, or reading what the instructor has written on a whiteboard).
   - **Broadcast Technology** – such forms of technology may range from slide projectors, and OHP projectors to television broadcasts – any form of technology that is functionally single source to multiple destination, and non-interactive.

4. **Student / Recipient**
   - Normally **human**, but may also include certain types of **animal** (consider guard dog training!), and in the future could be forms of **cybernetic systems** that require instruction to develop 'learned' capabilities.

5. **Response Encoding**
   - **Student Response Media,** this characterises any form of 'blank' media which may be used by the student to give an answer or response. Examples include the humble pen and exercise book, and application programs such as Microsoft Word.
   - **Training Resources,** these resources are used in the context of student responses to allow student practice; rock faces, climbing walls, ranges and real equipment all fall into this category, as do simulations.
   - **Auto-instructional materials**, also allow response encoding.

6. **Response Delivery**
   - Response delivery is normally **direct** or through **Communications Technologies**.

7. **Response Interpretation**
   - **Instructional facilitator (instructor, examiner).**
   - **Auto-instructional materials**, in systems with embedded logic, response interpretation may be algorithmic (i.e. conditional logic based on parameter values), this may in turn trigger (select) new forms of presentation or content selection, such as the remedial loop, or by triggering the involvement of the instructor through email.

A few types of instructional resource span multiple parts of the instructional environment, these are:

- **Instructional Media**: The term used to describe how stimulus messages are encoded and delivered to the student. While we characterise text books as instructional media, we do not generally characterise (for example) student exercise books handed in for marking as *instructional* media, though they constitute media on the basis that stimuli is being mediated between two individuals.

- **Communications Technology**: The term to describe technology that may be used to deliver two-way messages between instructor and student. Examples include the postal system, the telephone system, video conferencing or the internet.

- **Instructional Technology**: The term to describe both broadcast and communications technologies used in an instructional setting. Also includes aspects of instructional media 'hardware' used to deliver stimuli to the user, such as slide projectors, VTRs and DVD players.

Figure 5 shows the relationships between these key generic types of instructional resource in the instructional environment.

Mapping Training Tasks to the Instructional Environment

Having developed a comprehensive model of the Instructional Environment, we are in a position to compare like-with-like – to relate training task descriptions and instructional environment descriptions. There are four general principles that can be applied to this comparison:

1. **Support for required stimulus type:** For example, if the training task demands visual cues the instructional environment must supply these.

2. **Support for required level of stimulus fidelity**: The cues and feedback must be supported at a level of fidelity adequate not to introduce "instructional noise". This judgement is made with reference to the conditions of the training task. For example a flight simulator with a very low level of visual fidelity in representing the ground might be adequate to teach high altitude air combat, but be totally inadequate to teach aircraft landings.

3. **Support for required response type**: The instructional environment must support response feedback equivalent to the form required by the learning task, under the conditions specified in the Training Objective Specification. In this respect there is no substitute for the 'real thing', given the caveats of availability, risk and resource.

4. **Support for required level of response fidelity**: In this respect it is not sufficient to model the gross types of responses required but also to represent them at the necessary level.

In making such comparisons, we also to need to be aware of the constraints that occur within the instructional environment in satisfying what the training task demands. As an example, an aircraft marshalling simulator using a 15" screen is not going to adequately relay field of view attributes that this type of training requires.

Constraints on Stimulus Encoding and Delivery

Instructional media cannot encode all forms of stimulus, and what cannot be encoded cannot be transmitted or delivered. The 'internal senses', the vestibular sense and kinaesthesis cannot be captured in media – they must be represented through real environments or simulacra. The chemo-senses; gustation and olfaction while being external senses do not lend themselves to representation in media – hence we (luckily) do not have 'smellivision', and 'scratch and sniff' is a novelty item and not a major component of instructional media.

Haptics may be represented by physical models, but these, like 'the real thing' cannot necessarily be easily transmitted remotely. This leaves the visual and auditory senses, which luckily are the easiest to encode and transmit in media. Training resources can always encode the stimuli required by the learning task, but some alternatives are not always suitable for teaching due to cost, risk or availability. No-one would consider the use of real aircraft for practicing the handling of engine fires in flight for example.

Constraints on Response Encoding

A far greater restriction in the configuration of instructional resources is in the capture of student responses. For example, playing Doom will never teach anyone how to shoot an assault rifle. The reason for this is that the control mechanisms and effectors involved (mouse and keyboard vs. whole body posture with a real weapon) are too dissimilar for experiences within one environment to be meaningfully transferable into the other environment. This is not to denigrate the use of games or desktop simulation in training. Whilst there are limits to the extent that PC-based flight simulation packages can be used for training pilots (for example flying skills), they have also been proven for use in cockpit resource management training. In this sense learning tasks in the cognitive domain are easier to handle than psychomotor skills, as the dependence on response encoding is less stringent.

DISCUSSION

By considering training tasks in information processing terms, and focusing in the first instance on the stimuli that must be presented to the student and the responses that have to be captured from the student, we can start to identify which components must be present in the instructional environment for instruction to be possible, even at an early stage in the development of a capability concept.

One advantage of this approach is that for the purposes of training options analysis we do not have to characterise the training down to a training objective level, by aggregating training tasks by what they require in stimulus and response terms we can aggregate many training objectives under the same characterisation.

Of course, this is not the whole story. We have to consider what is going to be the most effective instructional method to use to cause the student to engage in the appropriate processing in order to deliver the required responses to the stimuli presented. The mapping of instructional methods onto the instructional environment is the next stage of development of the overall approach.

The final stage of development will be to determine how all the other factors that play a part in determining the instructional environment, such as cost, policy constraints, student distribution, instructor availability and infrastructure are represented. Consideration of these factors then determines which of the theoretically possible solutions, are viable in practice.

ACKNOWLEDGEMENTS

This work has been conducted as part of the Human Factors Integration Defence Technology Centre research programme funded by the UK MoD.

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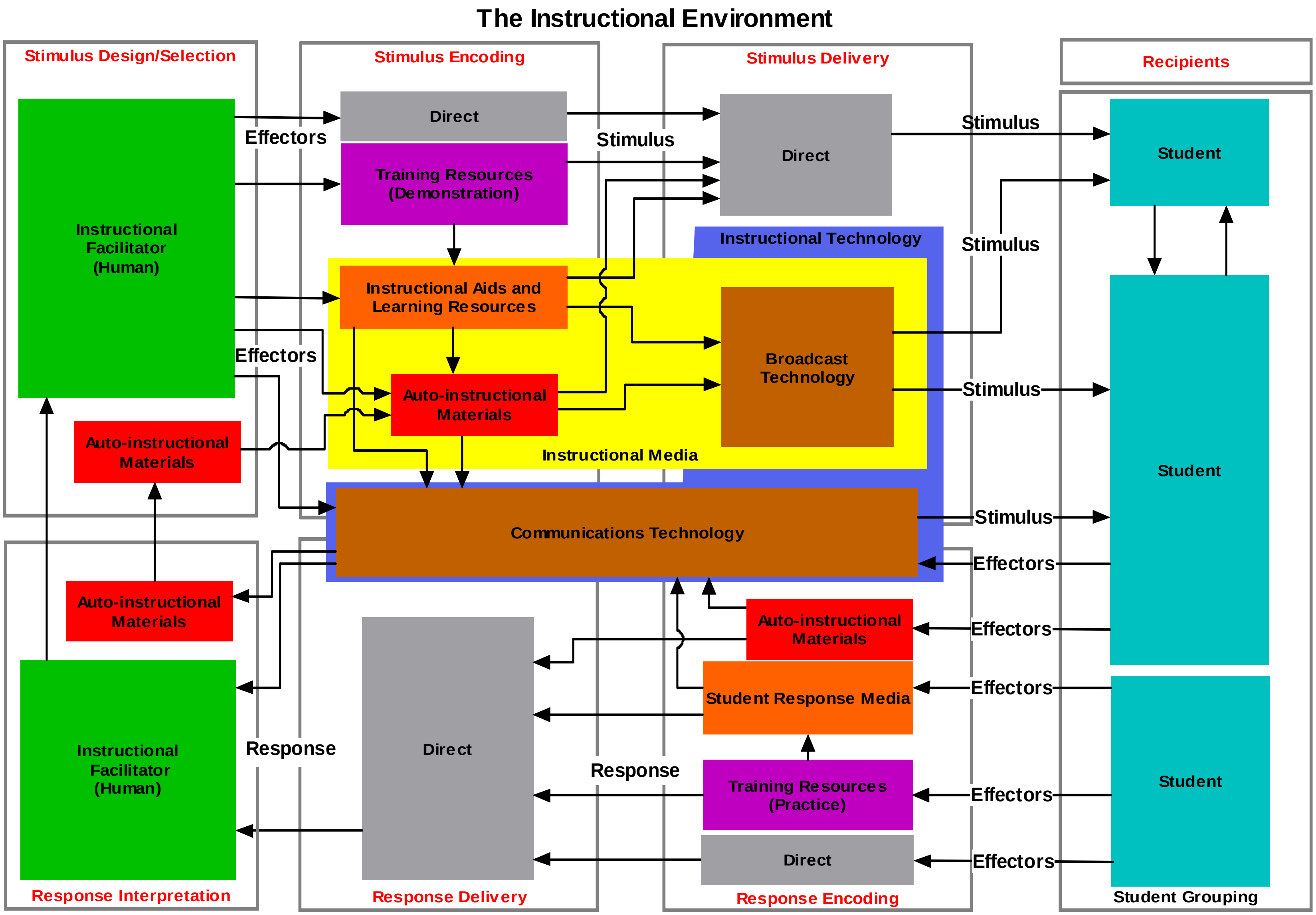

Figure 5. The Instructional Environment Model – indicating generic resource types and their relationships