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Relational memory generalization and integration in a transitive inference task with and without instructed awareness

Anita Munnelly [a,b,1], Simon Dymond [a,*]

[a] Department of Psychology, Swansea University, Singleton Park, Swansea SA2 8PP, United Kingdom
[b] School of Psychology, University College Dublin, Belfield, Dublin 4, Ireland

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ABSTRACT

Two experiments investigated the potential facilitative effects of prior instructed awareness and predetermined learning criteria on humans' ability to make transitive inference (TI) judgments. Participants were first exposed to a learning phase and required to learn five premise pairs (A+B−, B+C−, C+D−, D+E−, E+F−). Testing followed, where participants made judgments on novel non-endpoint (BD, BE and CE) and endpoint inferential pairs (AC, AD, AE, AF, BF, CF and DF), as well as learned premise pairs. Across both experiments, one group were made aware that the stimuli could be arranged in a hierarchy, while another group were not given this instruction. Results demonstrated that prior instructional task awareness led to a minor performance advantage, but that this difference was not significant. Furthermore, in Experiment 2, inferential test trial accuracy was not correlated with a post-experimental measure of awareness. Thus, the current findings suggest that successful TI task performance may occur in the absence of awareness, and that repeated exposure to learning and test phases may allow weak inferential performances to emerge gradually. Further research and alternative methods of measuring awareness and its role in TI are needed.

1. Introduction

Considerable research has been conducted on the role of conscious awareness in learning and memory. Studies have found evidence for learning in the absence of awareness (e.g., Bayley, Frascino, & Squire, 2005; Cleeremans, Destrebecqz, & Boyer, 1998), while other findings indicate that awareness may (Clark & Squire, 1998; Cohen & Eichenbaum, 1993) or may not (e.g., Mudrik, Breska, Lamy, & Deouell, 2011; Purkis & Lipp, 2001; Williams, 2005) be needed for some forms of higher-order memory tasks requiring the generalization and integration of learning. One such widely studied task is the transitive inference (TI) task, which is considered a hallmark of human and nonhuman reasoning abilities (Vasconcelos, 2008). In a typical TI task, overlapping pairs of simultaneous discriminations are trained, such as A+B−, B+C−, C+D−, and D+E− (where "+" indicates reinforced choices and "−" non-reinforced choices), before novel combinations of stimulus pairs (e.g., AE, BD) are presented in a test phase in the absence of feedback. Now, the AE test pair may be solved without reference to the intervening pairs, and A chosen over E, since during training A is always reinforced and E is never reinforced. On the other hand, the BD pair have comparable training histories since reinforcement is made available equally often for choices of B and D during training. Despite this, selection of B over D is predicted because D was paired with E during training, which was never reinforced (Ellenbogen, Hu, Payne, Titone, & Walker, 2007; Frank, Rudy & O'Reilly, 2003; Frank, Rudy, Levy, & O'Reilly, 2005; Greene, Spellman, Dusek, Eichenbaum, & Levy, 2001; Lazareva & Wasserman, 2010; Libben & Titone, 2008; Martin & Alsop, 2004; Merritt & Terrace, 2011; Moses, Villate, Binns, Davidson, & Ryan, 2008; Moses, Villate, & Ryan, 2006; Werchan & Gomez, 2013).

The ability to generalize learning and integrate information in TI tasks may be mediated by conscious awareness (Libben & Titone, 2008; Martin & Alsop, 2004; Moses et al., 2006, 2008). "Awareness" in this instance is said to refer to a conscious understanding that the stimuli may be ordered along a hierarchy, a representation of which is then inspected and used to make inferential judgements (Greene et al., 2001; Smith & Squire, 2005). Task awareness is usually measured via post-experimental questionnaires, despite the acknowledged limitations of such measures (e.g., Lovibond & Shanks, 2002). Greene et al. (2001) instructed one group of participants that the stimuli formed a hierarchy, while another group were instructed to learn the pairs by trial

* Corresponding author. Fax: +44 1792 295679.
E-mail addresses: anita.munnelly@ucd.ie (A. Munnelly), s.o.dymond@swansea.ac.uk (S. Dymond).
[1] Fax: +44 1792 295679.

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and error (see also, Libben & Titone, 2008). Measuring BD performance early during the learning phase assessed relational reasoning: after each block of learning trials, BD trials were tested (and retested). Greene et al. examined effects on subsequent performance and task awareness and found that instructed awareness led to faster learning and marginally greater accuracy on BD trials. Despite this, the group given no instructions performed significantly above chance on the BD test pair and that successful inferential performance was not correlated with a post-experimental measure of awareness. Furthermore, it was found that when performance on BD was near perfect, task awareness was not high, leading Greene et al. (2001) to propose that although explicit instructed awareness of the stimulus hierarchy is sufficient for TI, it may not be necessary. Additional, conflicting evidence however suggests that awareness of the stimulus hierarchy may in fact be a critical factor in TI (Martin & Alsop, 2004; Moses et al., 2006, 2008; Smith & Squire, 2005).

Evidence for the role of awareness, and whether or not instructed awareness facilitates generalization and integration of relational information, is therefore inconclusive and confounded by methodological shortcomings. For instance, the two studies to manipulate instructed awareness have employed differing learning and testing protocols and yielded contrasting results (Greene et al., 2001; Libben & Titone, 2008). That is, presenting the critical BD probe trials during learning may more readily identify the time course of the emergence of awareness and successful inferential performance, but it is confounded by the instructional manipulation. What are needed are unambiguous, separate demonstrations of the role of instructed awareness of the stimulus hierarchy and early BD testing on TI and post-experimental awareness measures. In addition, it may be beneficial to determine whether factors other than awareness, such as repeated exposure to learning and test phases enhance TI. That is, the ability to display accurate TI performances at test may rely on the establishment of stable patterns of responding during learning and test phases, rather than awareness.

Thus, in the present study we investigated the relationship between instructed awareness of the stimulus hierarchy, post-experimental awareness measures and methodological factors such as early BD probing and repeated learning and testing on the generalization and integration of memory in TI. In Experiment 1, one group of participants were instructed that the stimuli could be arranged in a hierarchy (Instructed group), while a second group were not given this information (Uninstructed group). Both groups then learned five premise pairs (A+B–, B+C–, C+D–, D+E– and E+F–), followed by testing with inferential, non-endpoint (BD, BE and CE), and endpoint pairs (AC, AD, AE, AF, BF, CF and DF) as well as the previously learned premise pairs (AB, BC, CD, DE and EF). Non-endpoint pairs represent the key trials in which generalized relational learning is demonstrated as all stimuli have equal histories of reinforcement and non-reinforcement (unlike endpoint pairs in which one stimulus is always reinforced and the other non-reinforced; Vasconcelos, 2008). In addition, Experiment 1 adopted a predetermined test mastery criterion and repeated exposure to learning and test phases, where necessary. Experiment 2 was similar except that the groups were presented with BD trials during learning trial-blocks and administered a post-experimental awareness questionnaire.

2. Materials and method: Experiment 1

2.1. Participants

Forty-three students, 20 men and 23 women, ranging in age from 18 to 33 years (M_{age} = 20.51, SD = 2.59) were recruited via the psychology subject pool at Swansea University. Participants were allocated partial course credit on completion of the study, and were randomly assigned to the Instructed (n = 20) or Uninstructed (n = 23) groups. Ethical approval was obtained from the Swansea University, Department of Psychology Ethics Committee prior to commencement.

2.2. Apparatus and stimuli

Six images randomly selected from the Kanji script were used as stimuli (see Fig. 1). The experimental task was programmed in E-Prime® (version 1.2), which controlled the presentation of all stimuli and recorded all responses.

2.3. Procedure

2.3.1. Learning phase

For participants in both groups, the learning phase began with the following onscreen instructions:

> During this phase you will be presented with two images in the middle right- and left-hand side of the computer screen. Your task is to learn to select the correct image. To select the image on the left, press the marked key on the left of the keyboard. To select the image on the right, press the marked key on the right of the keyboard. Sometimes the computer will give you feedback, and at other times it will not. The computer will tell you when this phase of the experiment is finished. Please press the spacebar to begin!

Additionally, participants in the Instructed group were told, *"There is an underlying hierarchy among the images. Your task is to learn this hierarchy"*; participants in the Uninstructed group were not given this information.

During this learning phase, all participants were presented with five adjacent stimulus pairs (A+B–, B+C–, C+D–, D+E– and E+F–; where "+" and "–" represent the reinforced and non-reinforced responses, respectively) and they were required to learn these pairs by trial and error. Both images from a pair were presented simultaneously in the middle of the computer screen. To select the

Fig. 1. The upper panel displays the Kanji images employed during training and testing. The images are labelled A, B, C, D, E and F (participants were never exposed to these labels). Also displayed are the premise, endpoint and non-endpoint test pairs.