

METACOGNITIVE CONTEXT CUEING IN MATHEMATICAL THINKING AND MATHEMATICS EDUCATION.

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Metacognition is here characterised by three themes: i) 'thinking as the object of thought', ii) 'thinking regulating thought' and iii) 'the feeling of knowing'. Traditional formulations of metacognition are criticised on their theoretical, operational and applied bases via these three themes, mainly because they denigrate the crucial role of affect in metacognition. Metacognition is more usefully defined as double context cueing: firstly to an appropriate ego-state of awareness, and secondly to a target/content emotional state with appropriate knowledge and ability response tendencies. Examples are discussed of metacognitive context cueing by internal/external co-constructed contexts, internal contexts, finely differentiated contexts and restrictive contexts that inhibit mathematics education. The necessary role of metacognitive context cueing in mathematical thought is discussed. The results of a research exploration into metacognitive context cueing are presented, including a simple credibility index for Likert responses. Directions are suggested for further research applications in mathematics education.

Critique of the Current Formulations of Metacognition

Flavell, in 1971, was one of the first to use the term 'metacognition' and later defined it as "knowledge or cognition that takes as its object or regulates any aspect of cognitive endeavor" (Flavell, 1978, p. 4). Later researchers have elaborated on Flavell's two themes - thinking as the object of thought, and thinking regulating thought. So Moshman (1979) distinguishes metacognition as thinking about one's theories as opposed to thinking with one's theories. Tyler (1983) further elaborates "This is to do with the thinking one does about thinking, the evaluation of one's own abilities and mental states, the selection of strategies to meet the task goals, and the monitoring and regulation of progress . . . Metacognition is becoming an increasingly popular topic for research." (p. 123).

Operational Restrictions - Down to the Choice of Strategies

Operationally Flavell's second theme has now degenerated. The 'regulation of thought' has operationally become 'the choice of strategies'. Kuhn, Amsel and O'Loughlin (1988) remark on this operational emphasis: "Most studies of metacognition are studies of cognition about how to learn and remember or studies of cognition involved in choosing and monitoring strategies to solve problems. Yet there remains a whole, relatively unstudied and very significant realm of metacognition consisting of cognition about what one knows one knows and how one knows it (though not in any formal, epistemological sense)." (p. 7) The "how one knows it" introduces a third theme to metacognition, 'the feeling of knowing or one's confidence in one's answers'.

Non-Affective Strategies for Facile Tasks

Since then we have met-a lot of metacognitive sub-categories such as metacognitive capacity, metacognitive knowledge, metacognitive activity, metacognitive strategies, metacognitive frameworks, metacognitive skill, metacognitive judgments, metaconsciousness, metamemory, etc. (Pinard, 1992; Borkowski, 1992; Slife & Weaver 1992; Weisberg, 1992). However, my criticism still applies that the regulation of thought entailed in these sub-categories has been operationally reduced to the mere selection of strategies. Further, the strategies operationalised frequently refer to facile forms of thinking more fitting to machines than to human cognition e.g. closed problem solving which minimises the role of affect, such as one to five step arithmetic word problems solvable by selection from the strategies taught (Melot & Corroyer, 1992; Montague, 1992; Okamoto, 1992).

Predominantly, studies in metacognitive regulation have avoided the generation and cuing of affect, and ignored other preconscious involvement in what they have studied - even though the regulation of cognition is so dependent on this preconscious involvement. For example Fischbein writes of the role of metacognition in mathematics education: "One of the fundamental tasks of mathematical education - as has been frequently emphasized in the present work - is to develop in students the capacity to distinguish between intuitive feelings, intuitive beliefs and formally supported convictions. ... Through metacognitive techniques the student has then to learn to see clearly the formal properties of the mathematical concepts used and to understand the intuitive sources of his misconceptions." (Fischbein, 1987, pp. 207,209) Unfortunately the same cognitive-affective structures may be responsible for both understanding the formal concepts and for being the source of the misconceptions. I believe researchers in metacognition need to turn their attention to the role of these cognitive-affective structures.

Who's Hiding Humunculus? - ad hoc 'Theory' and the Infinite Regress of Reductionism

Currently, metacognition is one of Psychology's hardest hit victims of reductionism. The mind is a bunch of functions - one for this and one for that - and one for executive control, regulating thought, telling all the others what to do. When we analyze the executive control to find which part controls the control we generate ad hoc new parts whose names are merely the description of their functions, and these functions generally ignore the interactions between the parts. Remember, we met-a lot of these parts above - the invented sub-categories of metacognition like the metamemory that reminds you to remember, but what reminds the metamemory to remind you? This is the infinite regress of reductionism, the ghost in the machine, the humunculus man inside the man, Plato's problem of who guards the guards, what monitors the monitor. Its metacognition pretending to explain cognition regulating thought and failing. Perhaps we could exchange one humunculus for a parallel processing model with cognitive-affective input (incorporating perceptions of small internal and external changes), where control was a partial feedback distributed function of the accommodating structure.

Tools of the Trade - Task-Talking Confounds the Process it Probes

Many of the research conclusions about metacognition are derived using the prevalent technique of task-related talk (Melothe, M.S. and Deering, P.D. 1992). The subject talks about the task while performing it. This task-talking is then used as a window onto how the subject's thoughts directed the performance. What this ignores is the considerable confounding interaction between task-talk and tasks of increasing cognitive-

affective complexity. Try dancing while explaining each step and movement of the body. Try giving a running commentary during sexual intercourse. In her review article on the mechanisms of metacognition Ann Brown (1987) notes that: "Asking subjects to report on internal events that are not readily available to such inspection may significantly impair the processes on which they must report. ... Requiring an expert golfer to describe his or her swing may, in fact, ruin the expert's swing, rather than help the novice." (pp. 76-77).

Misguided Application - Conscious Monitoring Paralyzes Expert Performance

An aim of this applied research is for a person who has been taught metacognitive strategies to be able to improve their task performance by consciously choosing the most appropriate strategy of which they are aware. However, rather than improving performance, this intrusive conscious monitoring to initiate conscious intervention paralyzes that powerful efficient intuitive spontaneity of reflexive thought and action we observe in expert performance. Consider: this concrete block is falling on my head. Thinks "shall I step back, or jump forward, or shall I quickly move to the side. Perhaps its time to just stand here and take this opportunity to end it all."

Thinking about Thinking - Next 'Thinking About Metacognition' the Study of Hyper-Metacognition?

Metacognition is cognition at a higher (meta) level of cognition. So there is no need to assume or investigate a new kind of cognition. As Flavell (1978) originally said it is still cognition but 'thought' is now the object of that cognition. This non-affective aspect of metacognition hardly warrants a new name. It warrants even less a field of study to itself.

Feeling of Knowing and Confidence in Being Right - Extensively Studied in Research on Intuition

Some researchers emphasise that third theme 'the feeling of knowing' and 'confidence in the correctness of an answer' as metacognitive abilities (Costermans, Lories and Ansay, 1992; Reder & Ritter 1992; Okamoto, 1992). My criticism of this research is that it has been done to much greater effect in research on intuition and insight (Bastick, 1982). Extensive measures of feeling of knowing and confidence in correctness of answer were used by Bastick (1979) in his studies of intuition and insight - e.g. Likert confidence ratings, narrowness of double estimates, variations in subject's physiological responses (gsr, heart rate, respiration etc.) on threat of electric shock for incorrect answers, etc. However, insight studies are not consistent with current formulations of metacognition and there have been logical and empirical criticisms of recent attempts to combine the feeling of knowing aspect of metacognition with experiments on insight problems (Weisberg, 1992). Researchers need some new theoretical formulation of metacognition that encompasses these important cognitive-affective aspects.

REDEFINITION OF METACOGNITION

I would like to more usefully redefine metacognition as context cuing of internal state learning via ego-state control. That is, my two themes are i) the cuing of ego-state control to elicit an appropriate state of awareness on the continuum from focussed to regressed and ii) the cuing, at that level of awareness, of a target state with appropriate learned responses.

This definition has two important commonalities with traditional metacognitive research. Firstly, in

reviews of the literature on context cuing of cognition it is usual to distinguish between cuing by the physical environment in which learning tasks place - the external context - and the cuing due to the subject's own emotional state - the internal context (e.g. Davies, 1986). We will find it useful to take into account that, from the prospective of the subject, internal and external contexts co-construct, but for some purposes of analysis we can maintain the traditional separate identifications of internal and external cuing contexts. Secondly, a useful intention of metacognition, as opposed to its restricted practice, is to study conscious, reflective awareness and deliberate control of the "higher intellectual functions." (Kuhn, et al. 1988, p. 32). I would retain and widen this intention and use the term 'metacognition' to mean the initiation and direction of higher cognitive-affective states and responses (like curiosity, insight, intentions, expectations, facts and strategies etc.) which, through practice, may become the reflexively initiated and directed components of expert performance.

Internal/External co-Constructed Context Cuing

We are very familiar with the fact that "thinking occurs in a context that significantly shapes its form and expression" (Kuhn, et al. 1988, p. ix) However, it is not only extreme contexts that evoke extreme emotional states like love, hate, fear or jealousy, for, as we shall see, contexts precisely differentiated - e.g. by the subtle nuances of synonyms - can evoke different emotional states in those sensitive to these differences. Dolan (1983) gives examples which illustrate what I have called the co-construction of internal and external contexts, their cuing of different states of awareness and the cuing of target emotional states with their associated learned responses:

For example, handing a hungry person his favorite kind of cookie or sandwich may elicit an externally observable response of reaching for the food, putting it up to his mouth, and beginning to chew. Internally, the cookie or sandwich may be eliciting certain associated feelings, remembered conversations, visual images, etc., connected to previous experiences with that particular object. ...When people are feeling ill, they tend to respond favorably to childhood foods associated with feelings of comfort and security. ... listening to music that was popular during the time of one's youth or a couple's courtship often functions to elicit happy feelings. Conversely, Vietnam veterans suffering from Post-Traumatic Stress Disorder sometimes evidence an unpleasant associational response to stimuli that remind them of events they experienced in combat. (pp. 75-76)

This context cuing is also so familiar to us from TV advertisements that associate benefits and preferred lifestyles with brand names so that either context cues the other.

Internal Context Cues

Anxiety - test anxiety, deadline anxiety - is a common internal cuing context. Rodin's 'The Thinker' illustrates another common example: using internal contexts of muscle sets to cue ego-control to appropriate states of awareness. We scratch our heads to puzzle. We pace the room to ponder. These learned muscle sets cue and maintain a state of awareness appropriate to resolving puzzlement.

Maladaptive Choice of Restrictive Context Cues

From research on creativity, what is particularly noticeable about some famous examples of contexts chosen to cue ego-control to a level of awareness suitable for creative work, is that they are unfortunately

maladaptive in that they restrict the amount of work that can be done - and hence, presumably, are difficult for the creator to change. A well known anecdotal example is of the fiction writer who needs to get blind drunk to tempt the muse. Then to stare at the blank sheet of paper in the typewriter to evoke content responses. Howard Gardner tells us about: "Richard Wagner, who had to work himself up into nearly psychotic frenzy before finally finding himself able to put pen to score" (Gardner, 1982, p. 123). Similarly Rosen, (1953) reports on the psychoanalysis of a mathematician with: "the marked inhibition of any desire to work at mathematics during the daylight hours " (p. 123). Famous mathematicians also used such contexts to cue states of awareness suitable for their work. Newman, (1956) reports that the mathematicians Helmholtz and Poincaré worked sitting upright at a table. Hadamard paced the room. J. Teeple (chemist) took two baths. Shaw ate vegetables (p. 2039).

Nearer our own experience are the context cuings of ego-control we find in mathematics classrooms. "Sit up straight at your desks and pay attention" focuses awareness. "Children, come and sit with me on the story mat" cues a regressed awareness. The non-verbal cues teachers individually use for their class management are examples of context cuing for their children. What is important for mathematics education is that, unfortunately, these context cues are implicit and not directly transferable out of that teacher's classroom. So we severely restrict our children's mathematical thinking because they become dependent on these context cues in the mathematics classroom but the children can not independently initiate them for themselves or use them out of the classroom.

Rituals and habits developed over a lifetime - habits like Kant's obsessively punctual routine - are commonly used for context cuing. Some affect-laden context cues for target states are so powerful that they directly cue both the ego-control to the appropriate level of awareness and also cue the target task/content relevant state. Marcel Proust's, now famous description of how a 'madeleine' biscuit and cup of tea evoked multimodal memories from his childhood with his aunt, is an example of how a powerful context can double cue (Proust, 1928, p. 54,58). In comparison to Proust's real life affect-laden multimodal example, many experiments on state dependent learning use tasks involving a minor modality and little affect - such as arithmetic or simple recognition - and those concerning internal states commonly use drug induced internal states (Slangen, 1991). These designs do not fully utilise affect and learned cuing. We would expect greater affect-dependent cognitive tasks to show greater experimental effects as Davies' (1986) review of the literature indicates.

Cuing by Finely Differentiated Contexts

Examples of finely differentiated context cuing are the target emotional sets evoked for the interpretation of language nuances. There are cultural cues that indicate regression is the appropriate mode of perception. Forms of religious observance and the use of unusual grammatical structures or archaic (poetic) words can cue a regressed, noncritical mode.

Any small difference in a context that can be sensed may act as a cue. "differences in the structure of stimuli do lead to different forms of processing." (Shepp, 1978, p. 123). Hermeneutic and discourse analysis shows us the possible cuing effects of even finer differentiations within the contexts of scientific literature. "The various scientific disciplines are differentiated by their respective discursive practices, or the modes of discourse propagated by scientific readers and writers." (Frawley, 1986, pp. 75-76). I can give as examples: i) The use of 'organism' when referring to 'people' which cues the reader into a behaviorist interpretation set; ii)

The choice of the word "input" in the following quote, instead of 'a stimulus field' or 'an apperceptive field' cues the 'information processing' interpretation set in the sensitised reader rather than a psychoanalytic or behavioural one; "the older child perceives input in an articulate, specific, or differentiated fashion." (Shepp, 1978, p. 123).

METACOGNITIVE CONTEXT CUING IN MATHEMATICAL THOUGHT

Ego-states required for mathematical thought range from the extremely regressed to the highly focused. Regressed states allow for heavily affect-weighted cognition (primary process thinking). It is in regressed states that we are open to holistic ideas, solutions guides, the beauty and aesthetic of mathematics. It is in such an ego-state that mathematical discoveries are made. It is in such an ego-state that we can appreciate Einstein's praise of Bohr's theory of the atom as "the highest form of musicality in the sphere of thought" (Einstein, 1949, pp. 46-47). At the other ego-state extreme we have minimum affect-weighted cognition (secondary process thinking) suitable for precision in detail - e.g. exact step-by-step deductive logic. During any particular problem solving task we need to change our ego-state appropriately to source ideas, select and apply techniques. Busse and Mansfield (1980) review the work of Kris (1952) which describes this traditional view of ego-state change during problem solving :

He (Kris, 1952) hypothesized that during this (inspirational) phase the ego temporarily loosens its control of thinking processes to permit a regression to a preconscious level of thinking. ... Kris believed that it is essential in creative thinking to temporarily abandon logical, rational thought that constricts thinking and prevents the formulation of new solutions. The person must deliberately allow day-dreams, fantasies, and the like to intrude upon his thinking. Later in an elaborational phase, the ideas are subjected to rigorous logical evaluation." (p. 32).

It is metacognitive context cuing of our ego-state control that gets us into the appropriate state of regressed or focussed awareness suitable for successive phases of mathematical thinking - then problem related contexts cue the relevant knowledge and ability responses (we hope). We have seen how muscle sets are a commonly used context cue. "I doubt if Einstein actually used his muscle fibers in his logic. He was rather referring to the feeling that he used to navigate his way through work. ... The organic senses are intimately involved in problem solving and send signals of impending success, unacceptable risk, and even unacceptable mediocrity." (Adams, 1986, pp. 75-76)

RESEARCH EXPLORATIONS - 'GETTING IN THE MOOD'

I have conducted some empirical research explorations to advance some tentative suggestions for future research designs and applications of metacognitive context cuing. 60 Australian, Education students aged 18-22 years old were asked how they got in the mood to do i) a task they liked, ii) a task they disliked and iii) a mathematics task. They were also trained in 'range answering' and asked to rate how much they liked or disliked the tasks and how easily they could do the exercises. Range Answering is a technique I have developed to assess the credibility of a Likert response - to assess, for example, a self-report of one's confidence in one's answer. Simply, if you asked two decorators for upper and lower estimates of how much it would be to decorate your house and the first said between \$1,000 and \$10,000 whereas the second said between \$2,000 and \$2,200 we can reasonable conclude from the smaller range that the second is more confident of what is involved. Range answering asks for an upper and lower response ("between what two

numbers ..") rather than only asking for one number, which would have been the mean. Using the two numbers, this mean is readily calculated and in addition it can be weighted by the range to give a more credible index for subsequent statistical analyses. I used a -100 to +100 scale and an index of the mean weighted by scale/range i.e. $0.5|x_u+x_l| \times 200/|x_u-x_l|$ which suitable weights more confident responses for least squares type analyses - x_u being the upper response, of course, and x_l being the lower response.

It was expected that subjects would find the unpleasant exercise more difficult than the pleasant one. This was not the case. The stronger the affect involved in the task, whether positive or negative, then the easier it was to re-experience this for the exercises. It was common for subjects to use personal ritual for context cuing the state of awareness required for the task - e.g. ritualistic dressing preparations for partying, ritually displaying all books pens and papers in preparation for homework. The most common preparation for liked tasks was to imagine what was going to happen. This cued an enjoyable anticipation. The most common cuings to motivate preparation for unpleasant tasks were 'resignation', and 'fear of punishment'. It was culturally interesting that descriptions of states for liked tasks commonly used metaphors for 'freedom' and 'power' while those for disliked tasks were of 'wasted effort'. In agreement with Yapko (1984) it was also noticeable that subjects changed the major modality used for describing liked and disliked tasks: "the dominant modality changes from context to context" (p. 123).

Task 'objects' were also used for cuing a state of readiness e.g. sports equipment, a particular piece of music. Results duplicated Strauch's (1983) observations on context cuing that: "A song may stir pleasant memories, the sight of a particular individual might cause anger or fear, or the sight of blood may cause nausea." (Strauch, 1983 p. 123). For example, subjects reported using particular songs to cue the required moods, a girl intimated that no matter how she felt - even if she was crying - the sight of her lover's face always made her happy. An important finding for future research designs is that - in agreement with attribution theory - the same external context can be co-constructed with the current internal context to cue different states in different subjects. So we should not expect to utilise one context for cuing similar states in all subjects. The results also showed care must be taken when interpreting Likert scales. Named bipolar dimensions for rating stated feelings were not as would be culturally expected and their meanings were differently co-constructed - for example a subject might state a feeling as 'boring', then give positive and negative extremes as 'powerful' and 'deadly', whereas another subject who coincidentally stated the same feeling might describe it using different extremes.

SUGGESTIONS FOR FURTHER RESEARCH

The typical person senses no control over their seemingly random metacognitive context cuing. Aims of research on metacognitive context cuing should be to understand more about these potentially useful experiences for the purpose of applying this knowledge to enhance expert performance. Teachers and children need to be aware that these processes have been working below their conscious level. Even brief classroom observations will reveal many convincing personalised examples that can be shown to teachers and children. Facilitating ego-states need to be identified as do ways of cuing their initiation and maintenance.

Teachers could explicitly choose context cues that their children could use to initiate their own thinking in or out of the classroom. Maladaptive context cuing could be interrupted and replaced by some facilitating context utilization e.g. using cognitive redefinition (Riskind, 1989). Current techniques from hypnosis e.g.

facilitating regression from secondary to more primary process thinking (Levin, & Harrison, 1976, p. 400), attribute theory, state dependent learning e.g. training associational cues (Dolan, 1983, pp. 176-177), Neuro-Linguistic Programming, etc. can be extended to facilitate reflexive application of metacognitive context cuing for enhancing individual's chosen expert performances.

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