Critical thinking instruction and contextual interference to increase cognitive flexibility in complex judgment

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Running head: COGNITIVE FLEXIBILITY IN COMPLEX JUDGMENT TASKS

Critical Thinking Instruction and Contextual Interference to Increase Cognitive Flexibility in Complex Judgment Tasks

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Abstract

Learning predictive relationships between cues and outcomes is a central aspect of many cognitive tasks. Studies on judgment and decision making have provided knowledge of how experienced decision makers approach complex decision problems. It seems to involve at least two types of skill: (1) recognition skills based on subject matter expertise (i.e., acquired cognitive schemas), that is, knowledge of relevant cues, their mutual interrelationships and the relationships with the criterion value that needs to be predicted, and (2) higher order critical thinking skills that serve to increase understanding by means of generalization and abstraction. Targeting training at these skills may improve cognitive flexibility through elaboration of the content (e.g., by generalisation, discrimination, or abstracting away from it). We established that instructional methods for implementing critical thinking and contextual interference, separately and in combination, can increase transfer of judgment skills to new tasks and contexts.

Critical Thinking Instruction and Contextual Interference to Increase Cognitive Flexibility in Complex Judgment Tasks

Research into judgment and decision making has shown that through experience people acquire knowledge that is structured in memory to facilitate instant retrieval of a solution when a situation is recognized as familiar (Chase & Simon, 1973; Klein, Moon, & Hoffman, 2006). However, in complex, ill structured task environments, simple analogies and prototypes do not suffice (Spiro & Jengh, 1997). According to Spiro, Feltovich, Jacobson, and Coulson (1992) ill-structured domains have two properties: a) each case in which knowledge has to be applied simultaneously and interactively involves multiple complex conceptual structures, and b) across comparable cases the conceptual structures involved and the way they interact differ. Van Merriënboer (1997) explains this in terms of the integration and coordination of two types of constituent skills tasks rely on. Tasks in complex cognitive domains are characterized by a large number of *non-recurrent* constituent skills (Van Merriënboer, 1997; Van Merriënboer & Kirschner, 2007). In contrast to *recurrent* constituent skills that rely on algorithmic, rule-based behavior (i.e., routine task aspects), *non-recurrent* constituent skills have to be performed in varying ways across problem situations. In other words, ill-structured tasks require a high degree of cognitive flexibility (Spiro et al., 1992). To acquire expertise in complex judgment tasks it is necessary to (a) understand the underlying theoretical principles of situations rather than relying on surface features (Chi, Feltovich, & Glaser, 1981; Larkin, McDermott, Simon, & Simon, 1980; Schmidt, Norman, & Boshuizen, 1990), and (b) to monitor, critically reflect on, and adapt decision strategies to the irregularity of problem situations (Klein, 1998; Klein, Orasanu, Calderwood, & Zsambok, 1993).

Deep understanding is known to be fostered by increasing the contextual interference between learning tasks (Battig, 1979; Magill & Hall, 1990). Contextual interference may be manipulated by the scheduling of learning tasks. Blocked task sequences, that is, sequences of learning tasks organised in blocks, with only one variation of a task being practised in each block (e.g., AAA-BBB-CCC), have low contextual interference. These have been found to lead to higher performance during training than random practice schedules (e.g., A-B-C-B-C-A-A-C-B), which have high contextual interference (Schneider, Healy, & Bourne, 1995). However, random practice schedules often result in better retention (learning) and transfer of skills to related tasks and situations (Greeno, 1964; Magill & Hall, 1990).

The cognitive skills that are required for monitoring and critically reflecting on one's own decision strategies may be acquired though critical thinking instruction. There are many different types of critical thinking instruction (see e.g., Abrami et al, 2008, Tsui, 1999). The method developed by Cohen and Freeman (1998) focuses on acquiring the experience necessary to recognize a vast amount of situations and simultaneous development of cognitive strategies such as indentifying evidence-conclusion relationships, reflection on observations and assumptions, criticizing the assumptions and mental model, adapting the mental model and formulating alternatives. Important in this approach is teaching the learner to deal with uncertainty and conflict and to encourage the learner to consider alternative explanations of the situation, in other words, question his or her epistemological beliefs (Whitmire, 2004). Not only are cognitive strategies acquired through this approach, but it is also expected to enhance processes of generalization and abstraction of the content of the tasks, because it encompasses elements of reflection and self-explanation (see e.g., Boud, Keogh, & Walker, 1985; Chi, 1996).

As a consequence, critical thinking processes may also increase interference during learning and as such support deep understanding of the learning materials. Therefore, both contextual interference and critical thinking may foster cognitive flexibility in complex judgment tasks. This should become evident in post-training performance, especially on far transfer tasks, that is, tasks that differ on both surface and structural features from the learning tasks (Quilici & Mayer, 1996), because such far transfer tasks do not call upon specific task procedures that were learnt, but instead require some abstract and general rules that can be adapted to new situations and tasks.

An interesting question is whether these two techniques can also be combined and if so, how. Under conditions of low contextual interference (i.e., blocked sequence of learning tasks), concurrent critical thinking processes may serve to increase contextual interference and benefit learning. However, in conditions where there is already high contextual interference between learning tasks (i.e., random sequence), engaging in critical thinking processes *concurrently* may overload available cognitive resources and therefore critical thinking about *previous* learning tasks may be a better strategy.

Thus, we arrive at the following propositions:

1. Critical thinking instruction enhances post training performance on complex judgment tasks.
2. Contextual interference enhances post training performance on complex judgment tasks.

3. For optimal learning benefit, in random practice critical thinking should be prompted retrospectively, whereas in blocked practice critical thinking should be prompted proactively.

Below, we will further elaborate on these propositions and present empirical evidence from our studies.

Critical Thinking Instruction Enhances Post Training Performance on Complex Judgment Tasks

In many situations, people's decisions are based on recognition of aspects of a situation, matching recognized aspects with earlier experiences, and forming a mental model of the current situation that implies a prototypical or sufficient decision option (Klein, Moon & Hoffman, 2006). Decisions in such a strategy are not made after all information is gathered, but rather are constructed along the way (Kuipers, Moskowitz & Kassirer, 1988), and therefore, early decisions may be based on simplified information and more relevant information for this decision may become available later in the process. Critically testing and evaluating one's mental model are therefore considered paramount in the decision process, especially when high stakes are involved, when problems are dynamic and complex, or both. These critical thinking skills typically are not part of a training program for professional decision making; they are mainly acquired as a result of experience in the field (Anderson, 1993; Klein, 1998; Klein et al., 1993). However, Freeman and Cohen (1996) developed an instructional strategy to teach these critical thinking skills.

Critical thinking is conceptualized as higher order thinking that is purposeful, reasoned, and goal directed (Abrami et al., 2008) . It is involved in solving problems, formulating inferences, calculating likelihoods, and making decisions (Frijters, Ten Dam, & Rijlaarsdam, 2008; Halpern, 2003). Critical thinking training as it was developed by Freeman and Cohen (1997) on the basis of their recognition/metacognition theory aims to develop two types of skill: Recognition and (meta)cognitive strategies. Recognition is the mechanism that enables experienced decision makers to select all relevant cues from the situation to activate or form an accurate mental model of this situation. To develop the experience necessary to recognize a vast amount of situations, an individual needs to be confronted with many different situations and discover the relevant cues, rather than being told what aspects or cues are important in what situations (Stout et al., 1997). Training should therefore be focused on presenting as many relevant problem situations as possible, and each situation should incorporate one or more relevant cues. From the breadth of experience that is provided in such training, the learner may generalize abstract representations that may guide judgment in novel situations (Morton & Munakata, 2002; Newell & Simon, 1972; Rougier, Noelle, Braver, Cohen & Reilly, 2005).

To facilitate such a process of generalization of abstract representations, critical thinking instruction incorporates stepwise instruction in the cognitive strategies that guide the judgment processes and are expected to support elaboration and understanding of the problem situations. These cognitive strategies involve skills to indentify evidence-conclusion relationships, criticize the mental model, adapt the mental model, and perform so called quick tests. Quick tests investigate whether there is sufficient time and opportunity to continue with elaborative processing, or whether the current mental model should serve as the basis for an immediate decision (Freeman & Cohen, 1996). Thus, the training program for military officers that Freeman and Cohen developed not only involved the presentation of many different problem situations, but also contained four specific steps to instruct and prompt the elaborative processes:

1. Develop a story (i.e., form a mental model) of the situation. Incorporate history, intentions and capacities of all parties involved in your story to explain all your observations and predict future events.
2. Test your story for conflicting and/or missing information. Try to explain all observations within one comprehensive and coherent story, even if these observations do not seem to be related to your story. Identify gaps in your story and make explicit assumptions to cover these gaps.
3. Evaluate your story. There is the devil's advocate that tells you—part of—your story is false. Try to come up with an alternative story that can also explain your observations. Which story is more plausible?
4. Develop plans and contingencies for the weakest assumptions in your story.

Analyses of historic events may serve as training materials for story building. In such analyses, the decision processes of professionals involved are often documented, and as a consequence, all elements of a comprehensive story can be easily identified. During story building, testing, and evaluating, it is necessary to constantly monitor whether critical thinking is still useful and wise in the current situation, or whether immediate action is required. The three preconditions that call for continued critical thinking are:

1. The risk of delay is acceptable.
2. The costs of a possible mistake are high.
3. The situation is not routine, but new and/or complex.

The critical thinking training by Freeman and Cohen (1996) starts with an initial instruction in the method, that is, an introduction to the theoretical background and the practical relevance of the approach, an explanation of the four critical thinking steps, and a demonstration of critical thinking being applied in a situation assessment and judgment problem. It continues with prompts being provided during practice to initiate the critical thinking processes in learners. The training has been empirically tested in several studies (e.g., Cohen, Freeman, & Thompson, 1998; Freeman & Cohen, 1996), but these studies were less than optimal. They were conducted in simplified training environments and compared the performance of participants who received critical thinking instruction with the performance of participants who did not receive any instruction at all. Furthermore, it was not established whether critical thinking had differential effects for transfer to tasks that differed on superficial features but shared the same underlying principles (near transfer) or tasks that differed on both superficial and underlying features (far transfer). Therefore, in two recent field studies (Helsdingen, Van den Bosch, Van Gog, & Van Merriënboer, 2009), we investigated the effects of critical thinking instruction on learning, near transfer, and far transfer. Participants received a military command and control training with six one-hour scenario-based exercises in both simplified and high fidelity learning environments. In both studies, half of the participants received instruction in critical thinking. The other half received the same exercises, but without critical thinking instruction. After the training, test scenarios were administered to both groups. Results provide support for the hypotheses that critical thinking instruction has a positive effect on transfer test performance and that this benefit is greater for far transfer performance than for near transfer performance.

Cohen and colleagues (Cohen et al., 1998; Freeman & Cohen, 1996) attributed the benefits of critical thinking instruction to acquiring an appropriate judgment making strategy. When students are taught critical thinking skills, they are less likely to make the typical mistakes in making judgements, such as giving in to confirmation bias (i.e., interpret new information so that it complies with the things you already know) or neglect of probability (i.e., disregard probability when making a decision under uncertainty; Halpern, 1997). Thus, they will show better overall performance on judgment tasks. In addition, the benefit especially for *far* transfer test performance that we found (Helsdingen et al,) suggests that participants also gain a deeper, more abstract level of understanding of the task content that specifically enables them to solve decision problems different from the learning problems on both a superficial and structural level (i.e. non-recurrent skills). Hence, when instruction in expert cognitive strategies is combined with a broad set of practice scenario's, the process of generalization of abstract representations is facilitated, leading to more cognitive flexibility and better transfer of judgment skill.

Contextual Interference Enhances Post Training Performance on Complex Judgment Tasks

As stated before, contextual interference may also enhance generalization and abstraction processes (De Croock, van Merriënboer, & Paas, 1998) and as a result, improve transfer across tasks or knowledge domains. Contextual interference may be increased by randomly scheduling learning tasks instead of a blocked presentation of these tasks. The effects of high contextual interference have been observed and studied extensively in the learning of motor tasks (Cross, Schmitt, & Grafton, 2007; Lee & Magill, 1983; Shea & Morgan, 1979; Simon, 2007), but are not unique to the motor learning domain. Studies on learning procedural tasks (Carlson, 1989; Carlson & Schneider, 1989; Carlson, Sullivan, & Schneider, 1989; Carlson & Yaure, 1990), cognitive operational tasks, such as interacting with automatic teller machines (Jamieson & Rogers, 2000), foreign vocabulary learning (Jacoby, 1978; Schneider, Healy, & Bourne, 1998, 2002), logical rules (Schneider, Healy, Ericsson, & Bourne, 1995), learning problem solving from worked examples (Paas & Van Merriënboer, 1994), or learning high-level cognitive tasks, such as troubleshooting a complex simulation of a chemical plant (De Croock et al., 1998), demonstrate that contextual interference is a general phenomenon that applies to a variety of learning tasks and contexts.

Only few studies have been conducted in the past to investigate the effects of task interference on learning complex judgment, in which the goal is to learn the complex relationships between several phenomena and predict the value of a distal variable (e.g., clinical diagnosis, weather forecast, threat assessment; Brehmer, 1973, 1977, 1979). Moreover, these studies measured performance during training, not on retention or transfer tests. Since training principles that are effective with relatively simple tasks are not necessarily effective for complex tasks as well (Spiro & Jehng, 1990; Wulf & Shea, 2002;), research is required to establish whether contextual interference is effective for retention and transfer in learning this type of complex judgment task. It is important to establish the most optimal training sequence for such tasks, because of the far reaching consequences that for example wrong clinical diagnoses or military judgments may have (Hogarth, 1980). Cognitive flexibility is paramount in such judgment problems: a physician for example, needs to learn to assess many different diseases and, equally important, needs to learn that different symptoms may lead to the same judgment since one patient may report one set of symptoms, whereas another patient having the same disease may report another set of symptoms. Therefore, a recent study by Helsdingen, Van Gog and Van Merriënboer (2009) explored the effects of contextual interference on learning and transfer of judgment skill to novel judgment problems.

In this study, two experiments were conducted, investigating the effects of contextual interference on retention (exp 1) and transfer (exp 2). In Experiment 1, participants' judgment accuracy on a retention test was higher after a random practice schedule (high contextual interference) than after a blocked or operational practice schedule. Experiment 2 demonstrated that judgment on a transfer test was also better after a random practice schedule than after a blocked schedule. Both experiments failed to show any effects of contextual interference on performance *during* learning. These findings show that the benefits of contextual interference for retention and transfer, which have been reported in the literature for perceptual-motor tasks, also apply to learning complex judgment skill, and moreover, may be achieved without detrimental effects on performance during practice.

For Optimal Learning Benefit, in Random Practice Critical Thinking Should Be Prompted Retrospectively, Whereas in Blocked Practice Critical Thinking Should Be Prompted Proactively

As we argued before, the benefits of critical thinking instruction and a random practice schedule both seem to originate from learners developing a generalized, more abstract representation of the learning tasks. Critical thinking instruction as developed by Freeman and Cohen (1996) encompasses instructional measures such as reflection (Boud, Keogh, & Walker, 1985) and prompted self-explanations during learning (Chi, 1996; Renkl, 1997; Stark, Mandl, Gruber, & Renkl, 2002) that may enhance this process of generalization and abstraction. Similarly, different explanations for the positive effects of random practice (e.g., Lee & Magill, 1983; Shea & Morgan, 1979; Schmidt & Bjork, 1992) have in common that they assume that a random practice schedule calls for more elaborative processing between or within tasks, and that these elaborative processes lead to deeper understanding and, consequently, better retention and transfer test performance.

However, such elaborate processing of the learning materials, both as a result of critical thinking instruction and contextual interference, requires working memory capacity of the learner. And at the same time, the learning task, that is making predictive judgments on the basis of several cues, also places a high demand on working memory, because learners need to address multiple elements of information (cues) simultaneously and integrate that into a criterion. A limited working memory capacity could easily be overloaded if more than a few chunks of information are processed at the same time (e.g., Baddeley, 1986; Miller, 1956). As Unsworth and Engle (2005) have shown, a reduced WM capacity, for example from a concurrent memory load, leads to a general decline in the ability to learn predictive relationships. But it is also known that organized, domain-specific, long-term memory knowledge structures (or schemas) allow people to overcome the limitations of working memory by "chunking" many elements of information into a single, higher-level element (see Chi, Glaser, & Rees, 1982; Larkin, McDermott, Simon, & Simon, 1980). And instructional measures such as critical thinking instruction and contextual interference are considered to support the development of these long-term memory schematic knowledge structures. Still, many researchers question the viability of teaching expert critical thinking skills to relative novices, claiming that novices in a particular domain may experience too high a workload from understanding the rules and principles of the domain and therefore do not have the cognitive resources available for (learning) higher order thinking skills (e.g., Kanfer & Ackerman, 1989; Winne, 1995). This high workload may be especially problematic, as research inspired by cognitive load theory (Sweller, Van Merriënboer, & Paas, 1998; Van Merriënboer & Sweller, 2005) has shown that adding additional instructions under high workload conditions (i.e., in which learners have little if any cognitive resources available) may not just be ineffective but actually hamper learning in the domain (for a review see, e.g., Kalyuga, Ayres, Chandler, & Sweller, 2003).

It is therefore important to establish if and how we can combine critical thinking instruction and contextual interference to generate maximum benefit for learning and transfer. Helsdingen, Van Gog and Van Merriënboer (2009) studied effects of critical thinking instruction in different practice schedules. It was expected that a learner's limited processing capacity would affect the success of combining the two measures. In conditions of high contextual interference, concurrently engaging a learning in critical thinking processes may be too demanding; whereas in conditions of low contextual interference, learners have the capacity to engage in critical thinking. Therefore, the timing of critical thinking prompts was manipulated: they could be given before the learning task they referred to, to encourage concurrent critical thinking; or they could be given after the learning task they referred to, enabling reflection on these tasks. In line with our hypotheses, the results showed that in a blocked schedule, the pro-active prompts yielded better performance on the far transfer test than a blocked schedule without prompts or with retrospective prompts. Hence, the drawbacks of blocked practice for far transfer performance may be overcome by critical thinking instruction. In a random practice schedule, retrospective prompts led to better scores than proactive or no prompts, here, the learner's processing capacity did not allow for concurrent critical thinking, but retrospective critical thinking improved deep understanding of the learning materials. This shows that both techniques can be successfully combined to stimulate transfer even further.

Discussion

Within the critical thinking research community, there is an ongoing debate on the issue of generalizability versus specificity of critical thinking skills (Siegel, 1991). Some studies have shown that special critical thinking programs usually do not result in long-lasting effects (Tsui, 1999). But at the same time, several authors point out that some general principles of critical thinking transcend specific subjects (e.g., Klaczynski, 2001; Stanovich & West, 2000; Tsui, 1999). As mentioned before, the transfer of skills across different tasks and knowledge domains is important because today's jobs require professionals to work in continuously changing contexts. Transfer of knowledge and skills across domains is a prerequisite for the ability to perform adequately in different contexts, that is, for cognitive flexibility, especially when the context contains inconsistent, unexpected, incomplete, and imperfect events (Spiro & Jenhg, 1990).

Still, the development of expertise in judgment and decision making skills is thought to be largely domain-specific (Ten Dam & Volman, 2002; Tsui, 1999). In their own domain, experienced decision makers quickly identify meaningful factors, realize what information they may be missing, recognize typical problems, and recall appropriate actions; in unfamiliar domains, the same decision makers may be at loss as to what the relevant factors are, thus making it impossible to realize missing information or come up with appropriate actions (Klein & Calderwood, 1991). Therefore, the challenge is to teach critical thinking in the context of specific meaningful subject matter, but yet in such a way that transfer to other tasks becomes possible (Brown, 1997; Frijters et al., 2008). Some researchers questioned the viability of such an approach, claiming that novices in a particular domain may experience too high a workload from understanding the rules and principles of the domain and therefore do not have the cognitive resources available for (learning) higher order thinking skills (e.g., Kanfer & Ackerman, 1989; Winne, 1995). However, our studies have shown that genuine novices (i.e., they had no prior experience whatsoever with the learning task), were able to profit from the critical thinking instruction and reflection prompts while learning a complex judgment task, provided the prompts were appropriately timed in their particular practice schedule: Pro-active in a blocked schedule and retrospective in a random schedule. And when critical thinking prompts were *not* appropriately timed, participants' performance indeed did not benefit from critical thinking instruction, possibly indicating they were not able to use the prompts due to high workload. But their performance was not negatively affected, which suggests that in high workload conditions learners may be able to ignore given prompts all together and focus on learning the specific rules and principles of the task without being distracted by them.

As stated earlier, instructional interventions that are successful in simple learning tasks do not always work for complex learning tasks (Wulf & Shea, 2002). Similarly, instructional interventions to increase cognitive flexibility and transfer may not be appropriate for different domains. The studies reported in this chapter considered complex judgment performance, in particular making predictive judgments based on integrating information from specific cues that occur in each case. However, in many judgments, nonoccurrence of a cue can be just as important as the occurrence of a cue (Mutter, Haggbloom, Plumlee & Schirmen, 2006). For example, in medical diagnosis, the absence of a symptom may provide as much diagnostic information as the presence of a symptom; in social attribution, the impression that someone does not like you may be based on the absence of overt words or actions that imply affection or interest. The study by Mutter et al. (2006) has shown that concurrent workload affect learning to utilize non-occurring cues differently than learning to utilize occurring cues. Therefore, the mediating effect of workload in the success of learning interventions may be different for different domains or learning tasks and future research could establish what task aspects interact with workload and instructional interventions on learning and transfer performance.

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