PROSPECTIVE EDUCATIONAL APPLICATIONS OF MENTAL SIMULATION: A META-REVIEW

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Abstract

This paper focuses on the potential of Mental Simulation (mentally rehearsing an action to enhance performance) as a powerful contemporary educational method. By means of a meta-review, it is examined which conditions impede or facilitate the effectiveness of MS. A computer search was conducted using Ovid PsycINFO. Reviews, meta-reviews or meta-analyses published between 1806-2006 were included. Current paper presents the results of 10 publications in which about 630 studies on mental simulation or mental practice are reviewed. According to the analyses, conditions that influence the effect of MS are the type of skill practiced, personal factors, time per trial, amount of trials, and instructional procedures. Based on these insights, it is reflected upon in which areas MS would be functional with regard to contemporary educational demands, such as for emotional, behavioral and (other) complex cognitive tasks.

Keywords: *Educational method; Mental simulation; Mental practice; Visualization; Imagery;*

Contemporary educational methods no longer have an emphasis on collective homogeneous classroom teaching but wish to support students in individually practicing what they need, when they need it (Brandenburg & Ellinger, 2003; O'Keeffe, Brady, Conlan, & Wade, 2006). An increasingly complex society -- with high-speed, global, and multimedia information exchange possibilities -- requires the mastery of more and more complex skills. This means that the learner must combine any blend of cognitive, motor, behavioral and/or emotional skills. Examples of such skills are improvisational, strategic or analytical skills as well as reasoning, problem solving and decision-making. Complex skills put a high cognitive strain on the student and call for effective and personalized practice that is available at the exact time that the student is ready for it (Kester, Kirschner, Van Merriënboer, & Baumer, 2001; Van Merriënboer, Clark, & de Croock, 2002). This indicates that contemporary education must focus on the individualized practice of complex cognitive skills, independent of time and place. To support this, a trend has developed towards highly advanced and multimedia supported learning. Technological solutions such as mobile learning, e-learning, and serious gaming are offered in order to achieve higher quality in terms of efficient and effective education (Rosenberg, 2000; Prensky, 2001; Keegan, 2002; Gee, 2003; Billings, 2005; Ting, 2005; Lieberman, 2006; Buckley & Anderson, 2006; Ritterfeld & Weber, 2006). Though the value of these high-tech solutions is acknowledged, simpler alternatives for effective learning should not be discarded as they may be equally sophisticated. What is more, some prevailing educational methods might not need much costly technology at all and instead rely on natural human abilities. One such method is ‘Mental Simulation’ (MS). MS (also known as ‘Mental Practice’) is a technique by which the mind creates a mental representation of a preconceived idea or action with the intent to practice in order to enhance performance (Hinshaw, 1991; Landau, Leynes, & Libkuman, 2001). An example of MS is when a tennis player closes his eyes and visualizes himself as he prepares for a perfect serve. He imagines how his arm feels when he lifts it to throw the ball in the air. He sees the ball rise over his head and pictures how his racket hits the ball in the exact right place and time. By mentally simulating his serve, he practices the motions (in his head) in order to enhance his performance in the next actual tennis match. Perhaps, much more potential lies in MS than has been uncovered so far. An effective method or educational tool that facilitates individualized practice of complex cognitive skills would agree with contemporary educational needs and consequently open up a new realm of possibilities in the educational field. Perhaps, a method with this potential has been lying right in front of us.

This paper presents a meta-review on MS integrating the knowledge base on MS using review articles. The goal is to provide insight in the conditions under which MS is effective. Based on this, it is speculated in which areas MS would be functional with regard to contemporary educational demands, such as for emotional, behavioral and (other) complex cognitive tasks.

Data collection

This meta-review started with a systematic literature search for all published articles related to mental simulation. A computer search was conducted using the internet database Ovid PsycINFO (1806-2006). A synonym of mental simulation, mental practice, was included in the search. At this stage, the term 'review' was not used in the search because of its broader connotation. A review article is an article that discusses multiple publications on MS or gives an overview of the current state of art on MS (American Psychological Association, 1996; Druckman, 2004). A special variant of a review article is a meta-analysis, which statistically integrates the findings of independent studies on MS. It was a precautionary measure to ensure that no relevant articles would be discarded or irrelevant articles selected. The search resulted in 388 hits, of which two hits were merged because they were double. From the resulting 387 articles a selection was made, based on the following principles. The article had to be a review, meta-review or meta-analysis. MS had to be the main topic of the article. The definition of 'mental simulation' had to refer to the concept of mentally rehearsing an action to practice it. It had to apply to healthy adults. Searches were limited to articles published in English. During this selection process it was found that the term 'mental simulation' or 'mental practice' is used in various contexts and connotations other than intended in this search. Articles that were excluded from consideration used the term 'mental simulation' for instance in relation to mind reading, therapy for (neurological) shortfall of bodily functions, self-fulfilling prophecy, etcetera. Twelve articles were eventually selected for interpretation for this meta-review. In spite of good library facilities in The Netherlands, two of these articles were not available, leaving ten (7 reviews and 3 meta-analyses, no meta-reviews were found) articles for our study.

Results

The findings of an estimated 630 studies have been summarized and reported in the 10 consulted reviews and meta-analyses. In the studied reviews and meta-analyses, various topics, factors and conditions of MS) were discussed. In the results section of this paper, the main topics have been identified and are organized into separate headings. The findings and discussions of the consulted literature on that specific topic can be found under the associated heading. This gives the reader a conveniently arranged overview of the factors and conditions that contribute to (or impede) the effectiveness of MS. Additionally, Table 1 provides the reader with an overview of the main topics of every consulted review or meta-analysis.

[Table 1 around here]

From Table 1 it is evident that information on the conditions under which MS is executed, is often missing. It is either not reported, or a variety of conditions have been taken together so conclusions about their separate influence can not be drawn. It is also noticeable that most articles focus on using MS for learning motor skills. Cognitive tasks are only occasionally included in the reviews.

From the reviews, it appears that a commonly used experimental design for determining the effect of MS is by using any of four conditions; subjects only engage in physical practice; subjects participate in one or several mental simulations with no physical practice; subjects engage in no practice at all; and -- less frequently used -- subjects engage in a combination of mental practice and physical practice. Noticeably, few experimental designs have a control group that practices something other that the relevant task.

General effects of Mental Simulation

The examined reviews on the subject of MS report moderately positive to very positive findings supporting the effectiveness of MS (Suinn, 1997; Richardson, 1967; Suinn, 1985; Murphy, 1990; Grouios, 1992; Murphy, 1994). It is unequivocally found that mentally practicing is more effective than engaging in no practice at all. However, in some instances, sole physical practice can be more beneficial than the same time spent engaging in sole mental practice or a combination of mental practice and physical practice (Suinn, 1997; Murphy, 1994). Meta analyses often provide a standardized statistic analysis of the overall effect size of MS. The consulted meta-analyses (Feltz & Landers, 1983; Hinshaw, 1991; Driskell, Copper, & Moran, 1994) lead to the same general conclusion that practice through MS is significantly more beneficial than no practice. Effect sizes of 0.48, 0.53 and 0.68 are reported, indicating that employment of MS influences performance positively when compared to no practice at all (Rosnow & Rosenthal, 1996; Druckman, 2004). This data suggests that an individual who practices through mental simulation will perform, on average, half a standard deviation (0.48) - or more (0.68)- better than an individual who did not practice at all (Murphy, 1994).

Type of skill

Motor skills and cognitive skills

An important distinction made in almost all reviewed articles is between practicing a motor skill and practicing a cognitive skill. Most experimental designs that have been published employ MS with a focus on the improvement of motor skills (often including strength tasks as a component of motor tasks). Many of these motor skills are related to sports, varying from throwing darts to skiing down a slope. Sport tasks are considered motor tasks, because performance assessments aim at the motor part of the task. Cognitive skills have to do with thinking, and conscious mental processes such as memory, perception, and problem solving. Examples of such skills are solving puzzles, verbal exercises, or navigating through labyrinths. One meta-analysis (Feltz et al., 1983) found results indicating that the effect of MS on cognitive tasks (M = 1.44) is significantly larger than the effect on motor (M = 0.43) or strength (M = 0.20) tasks. Indeed, it is argued that MS facilitates motor performance only in as far as the task encompasses cognitive elements. This notion is supported (Hinshaw, 1991) by the suggestion that the higher the level of cognitive involvement of a task, the greater the effect of MS. In one meta-analysis (Driskell et al., 1994), tasks were examined by the degree to which a task involved more or less cognitive components. The results showed that MS was more effective the more a task involved cognitive activities. Moreover, it was found that the degree to which components of motor tasks (strength, coordination and speed) are represented in a task, negatively correlates to the effectiveness of MS. The more a task includes the components strength and coordination, the less effect MS has on performance (Driskell et al., 1994).

The distinction between motor tasks and cognitive tasks appears to be significant in determining the effectiveness of MS. It can be concluded that, though research has focused on cognitive tasks to a much lesser extent, larger benefits can be expected from MS practicing cognitive skills.

Open and closed skills

In continuance of the previously discussed distinction between motor and cognitive tasks, there are other task-characteristics that might influence the effectiveness of MS. A task can for example be open or closed (Hinshaw, 1991). A closed skill is one that is largely dependent on the actions of the practitioner without much interference from external factors. Examples are diving, or dart-throwing. An open skill involves a higher degree of external influences and is characterized by improvisations and reactionary responses, such as tennis or basketball. It has been suggested that it is more difficult to mentally simulate an open skill, because it is harder to anticipate the needed skills (Hinshaw, 1991). Hence, one would have less control over the mental simulation and it would be less fruitful to use MS. Most consulted reviews do not support this idea. It is held by some (Feltz et al., 1983) that there is no significant difference to be found between open and closed skills. It is contended by others, that MS is indeed suitable, proficient even, for practicing skills that have unpredictable elements (Suinn, 1985). It is argued that MS will assist subjects in anticipating on and quickly adapting to changing scenarios. MS is reported to be used to envision unexpected problematic or distracting events (Suinn, 1985). In this way, subjects can practice instant adaptation to changing conditions and rehearse appropriate responses. A compromise between these two contrasting views is offered by the proposition that MS is generally more effective for simple (closed) motor tasks but is effective for complex (open) motor tasks when the subject is familiar, or experienced with this complex task (Suinn, 1985).

Whether a skill is open or closed might be a defining factor for the effectiveness of MS. However, the investigated literature is inconclusive in determining whether open or closed skills are more, less or equally proficiently practiced through MS.

Personal factors

Familiarity with the practiced skill

Familiarity with a task is in itself considered an influential condition for MS (Richardson, 1967). It is the conviction of some researchers that beginners, who are unfamiliar with a certain skill, have a higher learning potential and thus a steeper learning curve when it comes to practicing a skill with MS (Feltz et al., 1983). From some findings (Driskell et al., 1994), it seems that novices generate stronger mental practice effects for cognitive tasks than for physical tasks. This same result was not found for experienced subjects. They benefited equally well for both cognitive and physical tasks. This gives rise to the question whether familiarity with a skill positively influences the effectiveness of practicing with MS, and furthermore, if this might differ between cognitive and motor skills. It is argued that beginners at a motor task are at a larger risk of practicing a desired skill incorrectly, and thereby potentially worsening their performance instead of improving it (Suinn, 1997; Suinn, 1985; Hinshaw, 1991; Murphy, 1994). Their ignorance on how to perform the skill, leads to the incapacity to practice the ‘motions’ correctly. This supposition accounts for some findings in which MS did not improve, or even worsened performance (Suinn, 1997; Suinn, 1985). It is also found (Guillot & Collet, 2005) that the higher the expertise level, the more accurate a movement can be mentally rehearsed in terms of temporal organization of the movement. This indicates that the degree of expertise determines the awareness of the technical complexity of a movement, and thus the quality of the mental simulation.

Summarizing, though it is likely that a novice will initially have a steeper learning curve, there is a risk of practicing the ‘wrong’ motions of a motor task with MS, leading to poor performance. A higher expertise-level seems to generate performance enhancements for both cognitive and motor skills.

Familiarity with MS and perspective

Not only experience with the performed task might affect the success of MS, experience with MS technique is considered to have an effect on the measure of improved performance as well (Murphy, 1990; Hinshaw, 1991). A novice at MS is more likely to use an 'external' perspective in his or her simulation (Hinshaw, 1991). This means that the simulation of the action is visualized as if it is 'seen' from a distance. An external perspective implies a 'helicopter view' where one sees him- or herself performing the action as if from another's point of view. An 'internal' perspective means that the simulated action is perceived as through the eyes of the person performing the action. An internal imagery perspective is thought to be more useful in performance enhancement (Murphy, 1994). Comparing high-performance athletes has led to the finding that winning athletes are more likely to use an internal perspective when mentally simulating than their less successful competitors (Suinn, 1997). It is hypothesized that the relation between an internal perspective and success will be stronger for physical activities (Murphy, 1994). An internal perspective allows kinesthetic awareness, which, due to the nature of a physical task, may facilitate performance. Nevertheless, it is not conclusive that an internal representation is always most beneficial. An external perspective, for example, is believed to have a larger influence on confidence and self-efficacy than an internal perspective does (Hinshaw, 1991; Murphy, 1994). This too is believed to lead to better performance.

To summarize, familiarity with mentally practicing a motion may influence the perspective a simulator is likely to use. An internal perspective is thought to benefit performance because of the internal kinesthetic awareness that is practiced. An external perspective might influence confidence and self-efficacy.

Individual factors

Since MS is a mental exercise, and mental processes by definition occur inside one's head, it is subject to individual interpretation. Personal factors, such as gender, intelligence, spatial aptitude, concentration, and cognitive flexibility, to name a few, could all affect the manner in which a mental simulation is performed (Richardson, 1967; Hinshaw, 1991; Grouios, 1992). A realistic problem with MS is that it cannot be monitored, let alone controlled, how a person mentally practices a skill (Murphy, 1990). Even if an elaborate script is provided, individual interpretation or independent changes made to the script are unavoidable (Murphy, 1994). Also a person's imagery ability can influence the vividness with which a mental simulation is executed, and thus affect the effectiveness of MS (Hinshaw, 1991; Grouios, 1992). There has been no conclusive evidence to suggest a difference in ability to mentally simulate between men and women (Feltz et al., 1983; Hinshaw, 1991). Though, especially due to differences in spatial ability, the idea cannot be entirely discarded yet (Grouios, 1992). In conditions where MS is used to train for complex sports skills, involving reactionary or coping abilities, the individual aspect is even more likely to be of influence. For example, responses to stressful events, such as entering a competition, are highly individual (Hinshaw, 1991). The fact that individual interpretation during MS cannot be controlled, compromises the reliability of all experimentally found data to some extent (Murphy, 1990).

In conclusion, individual differences between people are likely to have at least some influence on the effect of MS on performance. Possibly, the more complex a skill, the more the individual factors play a part.

Motivation

Finally, a motivational factor must be considered. The effect of MS on performance could be compromised by the so-called Hawthorne effect (Richardson, 1967; Hinshaw, 1991; Grouios, 1992). The Hawthorne effect describes a motivational difference between groups that comes from disparities in received 'attention'. One group gets 'something' that the other group doesn't. It is hypothesized that 'control' groups will have received considerably less attention than groups in either the physical- or mental practice condition. The latter may have seen progress during practice, or otherwise gotten feedback on performance. Even if this is not so, spending time and effort in practicing a skill increases intrinsic motivation. Control groups often are not required to spend as much (if any) time on practicing. A liable consequence could be that control groups are less involved and thus less motivated to perform. The discrepancy in motivation to perform could, to some extent, account for the measured differences in performance between focus groups and control groups.

Time and trials

Duration of trials

Time may be of moderate to crucial influence on the effect of MS. MS sessions can vary from a unique two-minute trial, to a multitude of MS trials over a period of 8 weeks (Hinshaw, 1991). Feltz and Landers (1983) investigated the role of time on MS and found that practice sessions that lasted less than one minute or between 15 to 25 minutes were most effective. This rather remarkable bimodal relationship was reproduced in Hinshaw's meta-analysis (Hinshaw, 1991) who found that effect sizes were significantly larger for trials that lasted under one minute or between 10 to 15 minutes compared to trails that lasted between three and five minutes. Suinn (1997) examined this unconventional distribution of most ideal duration of MS. His suggestion was to correct for some extreme values by removing one 'outlying' study (that took 30 minutes per trial) and by eliminating all cognitive task studies (15 studies in total), leaving only motor and strength tasks. This resulted in a more linear relation between time and effectiveness of MS, indicating that the more practice, the better the performance. This linear relationship is challenged by other findings (Driskell et al., 1994) that indicate that, after reaching an optimum, an increasing duration of MS has a decreasing beneficial effect on performance. As a general resulting guideline from these findings, it is proposed that a training period should last around 20 minutes, no more (Driskell et al., 1994). Another time-related aspect of MS is the period between pre- and post-test (Grouios, 1992; Driskell et al., 1994). It is unclear if there is an optimal time span between pre- and post-tests (Feltz et al., 1983). Fifty years of research have lead to the conclusion that distributed MS is better than massed MS, indicating that an optimum time span between sessions could be determined (Suinn, 1985; Murphy, 1990). One review reports a significant negative relationship between retention interval and effect of MS, indicating that the longer the time span between pre- and post-test, the weaker the effect of MS (Driskell et al., 1994).

In brief, there is still much uncertainty regarding optimums in time (both spent mentally simulating and between MS sessions). Suggestions vary from bimodal to exponential to linear relationships.

Number of trials

No significant effect was found for the ideal number of trials (Feltz et al., 1983; Driskell et al., 1994), but effects were found for the number of repetitions per trial. As with the length of trials, a seemingly bimodal relationship was found between the amount of repetitions per MS session and effect on performance (Feltz et al., 1983). Practice effects were optimal for less than 6 repetitions or between 36 and 46 repetitions per trial. The correction for extreme values and cognitive task tests (Suinn, 1997) made this relationship a linear one. Though no distinction was made in these analyses between motor and cognitive tasks, it has been found that cognitive tasks are typically associated with far fewer trials (Feltz et al., 1983). Often, instructions do not specify how often a skill should be rehearsed mentally (Richardson, 1967; Grouios, 1992). The amount of repetitions per unit of time is therefore left entirely up to the individual. The time that an individual requires to simulate one movement is likely to affect the amount of repetitions that are iterated. It cannot be assumed, however, that a mental simulation of a movement takes the same time that performing the actual movement would. Depending on the type of skill that is practiced, the time used to mentally simulate this skill may vary (Guillot et al., 2005). For many 'simple' motor skills, the duration of the imagined movement is equal to that of performing the actual movement. The time it takes to perform both complex and attention-demanding movements, is disproportionately overestimated when mentally practiced (Guillot et al., 2005). For skills that require high attention levels or are considered difficult, it is harder to preserve the realistic temporal aspects of the movements. The time it takes to mentally simulate an action once may vary but the amount of repetitions per trial seems to influence the effect of MS on performance.

Procedures and instruction

How a mental simulation should be performed has not formally been documented or registered in the reviewed articles. In none of the consulted articles does its definition include requirements for its procedures. Consequently, MS has been offered by means of various methods (Murphy, 1990). Instructions vary from brief orders to close one's eyes and think of performing the skill, to audiovisual techniques that gradually guide the subject through a simulation. Examples of documented procedures are reading descriptions, listening to descriptions, verbalizing the skill, and audio-visual techniques (Grouios, 1992). Though some of these techniques have been compared (Hinshaw, 1991; Grouios, 1992), not enough research has been done to provide any insight in the most favorable nature of instruction. The content of a simulation is largely dependent on the instructions provided. If the simulation is guided, what type of guidance is most effective and how explicit should the details be? One review (Suinn, 1997) advises to at least include the following elements in every instruction to ensure maximum effectiveness: "scene setting" details, actions and responses, kinesthetic / proprioceptive / emotional descriptors, and possibly the desired outcome. Contrary to his view, it is posed that spontaneously generated simulations are more effective than those induced by too direct instruction (Hinshaw, 1991). From this literature research it is derived that explicit instruction has the risk of being overly directive, thereby inhibiting the spontaneity of an image. Implicit instruction would be more effective because it leaves more control of the image to the person simulating (Hinshaw, 1991).

In conclusion, very little attention has been paid to thorough and explicit instructional guidelines for using MS. Instructional guidelines could include time- and place recommendations but foremost, should include type and intensity of guidance during the simulation process.

Theoretical clarifications

Many of the above posed uncertainties might be founded in one question: *Why* does MS work? If a causal theory behind the workings of MS can be unraveled, would that not provide substantial insight in the conditions under which MS works optimally? Unfortunately, there is no clear-cut answer to why MS is effective. Many theories have been suggested of which the most prominent are illustrated below.

Motivational Theory

The motivational theory operates from the same pretext as the previously discussed Hawthorne effect. Due to the attention given to the task (through mentally practicing), an interest in the task is created. This interest manifests itself as an increase in motivation to perform (Suinn, 1997; Richardson, 1967; Grouios, 1992; Driskell et al., 1994). This motivation could, to some extent, account for increased levels of performance.

Symbolic learning

The symbolic learning theory contends that mental practice allows one to familiarize oneself with the symbolic elements of a task. Elements of performance can be symbolized and rehearsed, thereby aiding retention of these elements (Richardson, 1967; Driskell et al., 1994)). Symbolic learning is dependent on the degree to which there is a cognitive component in a task (Hinshaw, 1991). The theory states that strictly motor skills should show little or no effect due to MS but that cognitive learning is facilitated by mentally practicing the skill (Hinshaw, 1991).

Attentional-arousal

The attentional-arousal theory sustains that an ideal performance is reliant on optimal levels of physiological arousal and focused attention (Hinshaw, 1991). MS, in this light, would then serve as a preparation method to realize optimal performance of a skill (Feltz et al., 1983). Mental practice elicits feelings of competence and self-belief, thereby focusing attention and getting 'psyched up' for performance (Suinn, 1997; Murphy, 1990; Grouios, 1992). The low muscle innervations that accompany MS set the arousal level and prepare the performer for the action (Grouios, 1992).

Bio-informational theory

The bio-informational theory (strongly related to the mental muscle movement nodes theory mentioned by Grouios (1992)) holds that every overt and covert behavior creates a specific and unique pattern of interconnected nodes in the brain (Hinshaw, 1991). This pattern can be seen as a path of connected nodes that are activated every time the (overt or covert) action is repeated. Frequent repetition will result in a strengthening of the connection between the nodes in this pattern. MS works by mentally rehearsing the action and thereby reinforcing the connection between nodes in the appropriate network. Strengthening the network will result in quicker activation of the appropriate responses and thus in performance improvement (Suinn, 1997).

Psychoneuromuscular

According to the psychoneuromuscular theory, imagining movements results in actual, though minute, innervations of the appropriate muscles (Richardson, 1967; Driskell et al., 1994). Visual and kinesthetic feedback that would be provided when an overt action is performed is also provided mentally when a covert skill is practiced. Resulting neuromuscular innervations of a below-threshold magnitude may serve as a rehearsal mechanism (Suinn, 1985). This results in the ability to improve skills by covert practice. While some researchers do not find the neuromuscular theory very likely (Feltz et al., 1983), others refer to the amply gathered evidence. Several studies have shown physiological activity in the form of electromyographic (EMG) action potentials as a result of MS (Grouios, 1992). This activity is seen as proof that the improvement in performance is based on 'muscle memory' that has been practiced during mental simulation (Hinshaw, 1991).

Discussion and suggestions for future research

General effects

The findings of this review present a universal view on the value and effect of MS. It can be concluded that MS is effective. More precisely, MS is more effective than no practice, but not necessarily more effective than physical practice, or a combination of MS and physical practice. These results indicate that there are more and less ideal circumstances under which MS should be considered as a method of training. Principally, MS should not be used *instead* of physical practice but it is an excellent alternative when physical practice is not possible. This is a favorable outcome when it is placed in modern educational developments. Employment of MS provides great opportunities in the light of the current focus on time- and place independent learning (Ting, 2005). Moreover, since MS has proven effective for both motor and cognitive tasks, research should further focus on the possibilities of using MS to train complex tasks with any combination of cognitive, motor, behavioral and emotional components.

Type of skill

Cognitive skills are more effectively practiced with MS than motor skills. This finding is not as clear-cut as it may initially seem, because any skill involves some degree of cognition. Competitive sports, for example, require cognitive skills combining holistic coordination of concentration, timing, sequencing of actions, and dynamic attention to environmental cues (Suinn, 1985). The cognitive constituent of a motor task can range from minute to substantial. As such, any motor task requires certain cognitive skills, and even that a cognitive task may require some motor skills. Thus, perhaps it is better put that the higher the level of cognitive skills in a task, the more the improvement in performing this task can be facilitated by MS. Remarkably; most research on MS is directed at improving the performance tasks that primarily require motor skills. Why? The emphasis on motor performance seems odd since much more potential of MS lies in the improvement of cognitive skills. Moreover, for many educational purposes, the need for improvement of cognitive skills highly supersedes that of motor skills. Think of analytical skills, reasoning skills, verbal proficiency skills or reactionary skills. Such skills might be practiced by MS.

Whether a skill is open or closed seems to influence the effectiveness of MS, but it is uncertain how. On the one hand it is contended that whether a skill is open or closed does not matter much for the results of MS (Feltz et al., 1983). On the other hand it is asserted that MS is particularly suitable for practicing unexpected (open) events (Suinn, 1985). The contradiction in the results leads to believe that no precedent can be set yet. Anticipation on and reaction to the unpredictability of a task (typical for an open skill) require cognitive skills. Since it has been found that cognitive skills in particular can effectively be practiced with MS, it would be expected that open skills would benefit from practice with MS. A resolution to this uncertainty would give insight in the range of possible educational applications for MS. For some highly cognitive skills, the factor of unpredictability may play a major part. Consider skills such as strategic thinking, problem solving or improvisational proficiency. It would be interesting to know if MS can be of use in practicing these skills. In the light of the attentional-arousal theory or the motivational theory, it is conceivable that such skills can be practiced with MS. In this case, a mindset or an arousal level is triggered that helps improve performance. The psycho neuromuscular theory claims that improvement is due to specific repetitions of movements or thoughts. It may be much more difficult to practice movements or thoughts mentally that are subject to change.

An increase in complexity of a skill might pertain to the effectiveness of MS. Little research has been performed on this. Complexity in this sense *might* be related to open and closed skills. Task difficulty is mostly due to increased cognitive factors (Guillot et al., 2005). It can be reasoned that a motor task gets more complicated as it requires a larger cognitive strain. An open skill might be perceived as more complex because in addition to performing the motor skill, certain cognitive skills (such as strategic planning or reactionary responses) are called upon simultaneously. In continuance of the discussion on open and closed skills, it could be reasoned that an increase in cognitive load, and thus in complexity, might influence the effectiveness of MS. Research is required on the influence of cognitive load and complexity of a skill on the effectiveness of MS.

It has also been suggested that open skills can only be effectively practiced through MS when the participant is already familiar with the skill. This implies that if it concerns an open skill, one needs certain basic knowledge of the skill in order to practice effectively. Perhaps, this is related to the presumed increase in complexity of an open skill. This finding coincides with the bio-informational theory, assuming a 'schema' or a connected network in the brain. The necessity to have an activated network for performance improvement might increase as the complexity of the task increases. Complex learning is a lengthy process requiring learners' motivational states and levels of expertise development to be taken into account (Van Merriënboer & Sweller, 2005). This indicates that with open skills, the use of MS as an educational approach should be preceded by other practice methods.

A limitation of this study is that it relies on reviews as sources of information: Although empirical studies might have been performed on types of skill, the reviews under study did not convey such information. The still under-acknowledged potential of MS in practicing cognitive tasks needs further investigation. Does the nature of a task (open or closed) coincide with its level of cognitive strain? And does this in turn have influence on the effectiveness of MS? Does the complexity of a task make MS more or less suitable for practice, or is this again linked to the level of cognitive elements in the task? And finally, does it help if the subject is familiar with the skill? When these questions have been answered, the true potential of MS for various educational purposes can be established.

Personal factors

Familiarity with a skill facilitates MS because one knows what to practice. Novices benefit from MS more for cognitive tasks than for motor tasks. Experts benefit from MS for both. The bio-informational theory can largely support this finding. It seems that an existing mental schema is needed for motor skills in order to benefit from MS. Once a network of the appropriate interconnected nodes has been formed, the schema can then be reinforced through MS. Thus a beginner (not in possession of such a network) will not improve his performance on the motor task by means of MS. However, this existing mental schema does not appear necessary for cognitive skills. This might imply one of several options. It could simply mean that cognitive skills do not require an existing mental schema to build on, because the cognitive skill is not dependant on only one correct way of performance. Individual differences in performing the skill are less harmful. It could also be that cognitive tasks are learned in a different way than motor tasks. The symbolic learning theory for example states that MS should hardly, if at all, be effective for pure motor tasks because MS only facilitates mentally practicing the symbolic elements of the skill. Thus the effect of practice is dependant on the degree to which there is a cognitive component in the task.

Whether a participant engages in MS with an internal or an external perspective, seems to influence the outcomes of practice (Murphy, 1994). Differences in perspective are based on practicing motor skills. Since MS is more effective when applied to cognitive skills, it would be interesting to discover if the same is true for such skills.

A recurring theme in the literature on MS is the motivational factor. Hypothesized increases in confidence, self-efficacy, and intrinsic motivation all point towards a facet of MS that influences a participant's mindset. This harmonizes with more than one theoretical explanation of MS. The attentional-arousal theory relates improvement of performance to increased physiological arousal levels and focused attention due to MS. In this light, MS is seen as a 'psyching' method to prepare body and mind for performance. The motivational theory concurs with the idea that mental preparation will increase levels of motivation, and thus performance.

Differences amongst individuals can influence the effect of MS. Future research might focus on which 'inherent' personal factors (such as visuo-spatial ability) are optimal for MS, but also which 'external' personal factors (such as experience) facilitate effective practice. It would be advisable to differentiate between motor and cognitive tasks in this respect, as the personal prerequisites for each might differ.

Time and trials

The relation between the time spent engaging in MS and performance is not yet conclusive. Exclusion of cognitive-based experiments resulted in a linear relationship between time and effect of practice (Suinn, 1997). This might indicate that there is a difference in optimum for motor and cognitive skills. Another possible explanation could be that cognitive skills have not been given as much attention as needed to determine the same linear relationship. This is supported by the finding that, generally, cognitive tasks are practiced in far fewer trials than motor tasks (Feltz et al., 1983).

As the difficulty of a task increases, it takes longer to mentally simulate the task (Guillot et al., 2005). This means that for a more complex task, fewer iterations are made per unit of time. In effect, the more complex a task, the less practice a subject is likely to have per unit of time. This might have grave yet, until now, unexplored consequences. It would mean that a comparison between complex and less complex tasks should be corrected for the fact that practicing a skill takes longer when a task is more difficult. The longer it takes to practice, the less effective practice one gets per unit of time. Assuming that a complex task has larger cognitive elements, taking together cognitive tasks and motor tasks in the calculation of the optimal time spent on MS would distort the relationship. When cognitive tasks are extracted from the equation, a linear relationship is revealed. This supports the notion that the complex cognitive tasks likely take longer to mentally simulate than simple motor tasks. And that indeed a linear relationship exists between time and effect, only it differs depending on the degree of cognitive elements in the task.

Time can be a crucial factor in establishing optimal procedures for MS. Not only the amount of time spent simulating, but also how this time is spent (the amount of iterations per unit of time) seem to be important. Type of task (cognitive or motor) and complexity of the task play a role in determining optimal time-management for MS. This too must be taken into account in further investigations.

Procedure and instruction

Despite extensive research on MS, insufficient attention has been paid to defining the optimal procedures for MS. As a result, there are large differences in instruction and execution of mental simulations for most conducted experiments. In the studied reviews, hardly any guidelines have been developed to give advice on manners of instruction. This is perhaps the biggest gap that needs to be filled in order to effectively use MS. Again, our study relied on reviews as sources of information. It would be interesting to determine if there are original empirical articles that studied the differences in value between a more spontaneous (Hinshaw, 1991) versus a highly directive (Suinn, 1997) instruction.

Perhaps there is also a difference between the optimal procedures for cognitive tasks and motor tasks. Some indications about an optimal procedure were found in a study on health behavior: MS instructions that aimed at the process for attaining a behavior goal were much more effective than MS instructions that aimed at the goal itself (Taylor, Pham, Rivkin, & Armor, 1998). Individual differences between people surely contribute to differences in how a practice-situation is mentally simulated. Every person has a unique starting point through personal experience, perspective and motivation. Differences in individual approach to MS are likely to influence the results of practice. In this light, the necessity for clear and unambiguous instructional design becomes even more apparent. Clear instructions can provide general simulation-guidelines and improve uniformity between simulators.

Differences in instruction and oftentimes disregard for the way in which a subject chooses to mentally simulate, result in a vague and indefinite applicability of MS. This makes it impossible to translate its use to other domains and educational purposes.

Theories

Most theories can, at least partly, account for the effectiveness of MS. It is conceivable that none of these theories are (entirely) correct, and that none are (entirely) false. Some theories appear to account for the learning of motor skills; others explain increased performance for cognitive elements of the skills. Measurable evidence, such as the minute contractions of muscles or brain activity in the appropriate regions gives reason to take biological and neurological explanations seriously (Murphy, 1990). This, however, should not diminish the potential value of theories that focus on motivational or symbolic aspects of MS. The individual value of each theory contributes to a greater understanding of the processes of our brains and bodies that underlie the effectiveness of MS.

The potential of Mental Simulation as an educational method

The effectiveness of MS for both motor and cognitive tasks has been established beyond reasonable doubt. Also, insight has been given in what specific conditions facilitate or impede the effect of MS. In order to launch MS as a strong tool for educational purposes, it is important that its potential is fully evaluated. The power of the mental apparatus through ‘thought’ is already utilized in other fields such as emotion management, cognitive behavior therapy and behavior management. The relation between thoughts and emotions for example becomes evident in the experiment of Druckman & Bjork (Druckman, 2004) who have found that, paradoxically, the suppression of a specific thought, in fact increases the emotional power of this thought. Thoughts and emotions are not only related, thoughts can be geared towards influencing emotions. MS shares a fundamental approach with that used in cognitive behavior therapy; the notion that actions are the product of thoughts and that consequently, interventions in thinking can lead to changes in behavior (Beck, 1976; Greig, 2007). The visualization of desired behavior or an emotional state is practiced in cognitive behavior therapy. Thus in this field, ‘mentally simulating’ a desired outcome has been proven very successful in actually achieving this outcome. Behavior management through MS, has been successfully implemented by doctors who help patients to adhere to medical recommendations. By visualizing, for instance, how and when medication could be taken on a typical day, patients were more confident that they could be compliant (Theunissen, De Ridder, Bensing, & Rutten, 2003).

[Table 2 around here]

Further applicability of MS should be investigated in the light of its effectiveness in other fields. Table 2 gives an overview of potential fields of application for MS. The Table briefly depicts the possibility of using MS in relation to emotion management, behavior skills and (other) complex cognitive skills. A theoretical reference is inserted in the Table to justify such applications of MS. In the last column, the challenges that are anticipated in using MS for these purposes are described.

In brief, a wide range of possibilities exists where MS can be directed at aiding improvement of a desired skill. Mental Simulation harmonizes with contemporary educational requirements as it can be tailored to a student’s specific needs and is suitable for practicing (complex) cognitive skills. Moreover, the path seems to be open to emotional and behavioral skills. It can be concluded that MS is a low-tech method that supports time-and place independent learning, improves performance for a variety of skills and heightens motivation. Its potential educational value is promising.

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Table 1. Overview of main findings per reviewed article

Nr	1ste Author	Nr of discussed publications	Goal of the review	Type of tasks	Type of MS	Significant results	Role of instructor
1	Feltz, D. L.	60	Conduct a meta-analysis to determine effectiveness of MS.	Motor, strength& cognitive tasks. Open/ closed	Variable or undefined	MS is more effective than no practice. Cognitive tasks have larger effect sizes than motor tasks	Undefined
2	Richardson, A.	25	Explaining how improvement occurs through MS with a focus on methodological issues.	Motor tasks	Undefined	-	Undefined
3	Murphy, S. M. (a)	76	A review to critically examine research related to sport performance and imagery interventions.	Motor tasks	Internal vs. external and undefined	MS is effective in influencing performance. Confusion stems from the different ways in which MS is viewed by researchers.	Undefined
4	Hinshaw, K. E.	21	Conduct a meta-analysis to provide an overview of the variables that mediate the size and direction of MS effects.	Motor, cognitive and strength tasks	Internal, external, relaxation techniques and undefined	Significant benefit to performance with mental practice compared to no practice. Larger effect size for internal than external simulation.	Visual, audio, or written, instruction. Or a combination. Implicit& explicit instruction. Or not reported.
5	Suinn, R. M. (a)	±112	Provide a review to determine the use of MS by athletes, facts on MS, unproven thoughts on MS, and theoretic explanations.	Motor tasks	Variable. E.g. Practicing correct vs. incorrect movements, visualization	There is no clear definition of MS, and no procedural consensus on how to apply it.	Undefined

6	Suinn, R. M. (b)	±38	Provide a review on imagery rehearsal in sports, with the goal of suggesting implications for behavioral therapy.	Motor tasks	Variable	Implications for behavior therapy are:	Undefined
7	Grouios, G.	±98	Present a review of the work on MS, possible explanations, several methodological problems, and optimal procedures.	Motor skills	Practicing novel skills vs. expert skills	Review of the work on MS so far completed	Reading descriptions, listening to descriptions, verbalizing about the skill, audio-visual techniques
8	Murphy, S. M. (b)	±71	Investigate the use of imagery in sport psychology by identifying the lack of development of MS due to different possible models of imagery.	Motor skills	Variable. Preparatory arousal, imagery, self-talk, relaxation, attentional focus	Suggestions for further research	Undefined
9	Driskell, J. E.	35	Conduct a meta-analysis to determine the effect of MS on performance and identify conditions under which MS is most effective.	Motor and cognitive	Variable	MS has a significant effect on performance. Effectiveness is moderated by type of task, retention interval and length/duration of MS.	Undefined
10	Guillot, A.	±94	Provide a review on the duration of mentally simulated movement.	Motor tasks	Complex movements, dynamic parts of movement	Results show systematic and disproportionate overestimation of actual duration, and a relationship between complex motor skills and MI duration.	Undefined

Notes: Undefined: no data available or reported. Variable: data varies in the pool of articles/researches that have been taken together;

Table 2. Potential of MS in learning contemporary demanded skills

Contemporary demanded skills	**Theoretical backbone**	**Challenges and required research on MS**
Emotion management skills		
Performing under stress / pressure	As in cognitive behavior therapy, 'exposure' (in one's imagination) to a situation that triggers intense emotions can be helpful in learning how to cope in these circumstances.	The influence of emotions on a task (whether it be a motor or cognitive task) have not yet been investigated in relation to MS. Experience from the field of cognitive behavior therapy should be used to further explore these options.
Behavior skills		
Enhancing the execution of desired behavior (learning a routine)	Mentally simulating the process of achieving behavior goals is more effective than mentally simulating the goal itself	It should be determined for all types of tasks which method for offering MS are most effective as has been found true for behavioral skills.
Complex cognitive skills		
Improvisation	Attentional-arousal theory: optimal levels of physiological arousal and focused attention aid improvisational skills	Improvisation is an 'open' task, it cannot be predicted what exactly will happen. It requires much of one's cognitive capacity. Research must be done to determine the use of MS in practicing open skills.
Strategic / Analytical skills	Symbolic learning theory: analytical strategies can be symbolized and rehearsed and applied more quickly and effectively	Individual factors play a large part with strategic and analytical skills. One's intelligence, spatial aptitude, concentration, and cognitive flexibility may all influence how well one performs. While investigating the use of MS for strategic skills, this must be taken into account
Reasoning / Problem solving / Decision making	Bio-informational theory: mentally rehearsing an action will result in quicker activation of the appropriate responses and thus in performance improvement	These are complex tasks that will most likely need longer simulation-times. With such complex tasks suitable guidance in the simulation might be imperative. For these tasks, it must be investigated which instructions and guidance are most effective.