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Modelling skill acquisition in acquired brain injury

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Abstract

Acquired brain injury (ABI) is a debilitating condition often requiring extensive rehabilitation. Although cognitive rehabilitation is concerned with overcoming a skills deficit, the application of skill acquisition research in this context has been non-existent. Examining post-injury learning in terms of the qualitative variables associated with different phases of skill acquisition is likely to be beneficial in assessing patient status and monitoring progress, as well as identifying changing needs over the course of learning. However, current models of skill acquisition overlook the potential impact of variables such as emotion, implicit learning, metacognition, motivation, and strategies that can be leveraged to improve skill acquisition. The current paper attempts to lay the groundwork for modelling and improving skill acquisition in ABI.

Every day, people prepare food, drive, interact with technology, and engage in a variety of tasks that involve skilled behaviour. The art of skill acquisition is inextricably linked with daily functioning and thus has implications for managing self-care and independent living. However, it is an unfortunate fact that many people have trouble acquiring even the most basic skills (Anderson, 1982). Among these people, are those coming to terms with cognitive impairment due to acquired brain injury (ABI). Cognitive impairment in ABI is heterogenous and may include attentional dysfunction; dependence/lack of initiative; difficulty executing novel activity; memory impairment or loss; poor organisation and planning; poor self-monitoring and self-regulation; and inability to benefit from experience (Curran, 2004; Ducharme, 2003; Lynch, 2002; Obrzut & Hynd, 1987; Schlund, 1999; van der Broek, 1999).

ABI is on the increase (Limond & Leeke, 2005). In fact, one Australian community reported an annual incidence of 100 cases per 100,000 residents (Tate, McDonald, & Lulham, 1998). Sixty-two per cent of ABIs are classified as mild and 36% as moderate or severe, with incidence highest in the 15 – 24 age bracket (Tate et al., 1998). The severity of impairment is a major determinant of the patient's return to instrumental daily living activity (Mateer, 2003; Ownsworth & McKenna, 2004; van der Broek, 1999). Thus, the need to address cognitive impairment is imperative, yet the issue of how to teach or re-teach the cognitively impaired is controversial (Limond & Leeke, 2005).

ABI and cognitive rehabilitation

Growing appreciation of the psychosocial sequelae associated with ABI has led to heightened interest in cognitive rehabilitation (van den Broek, 1999); the primary aim being to improve an individual's capacity to process and utilise incoming information in daily functioning (Wilson, 2002). A key issue is whether cognitive rehabilitation should focus on (a) retraining, reviving, or restoring cognitive functioning, or (b) training the patient to work around cognitive impairment (Lynch, 2002; Wilson, 2002). The first approach is based on the assumption that the brain is like a "mental muscle" that can be strengthened through repetition, while the second approach is based on the assumption that impairment or loss of functioning is permanent, but can be overcome to some extent through the application of compensatory strategies (Ownsworth & McKenna, 2004). Although research has drawn attention to the need to examine the brain's capacity for recovery or

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reorganisation of functioning after injury (Mateer & Kerns, 2000), generally speaking restoration is not a realistic goal, with little support for remediation beyond the natural recovery phase (Ownsworth & McKenna, 2004). Furthermore, restoration is unlikely to generalise beyond training (Lynch, 2002). Given that injury is relatively fixed, compensation is likely to be more effective (McKerracher, Powell, & Oyebode, 2005; Tate, 1997). People with ABI are capable of learning compensatory strategies even in the acute stage of recovery (Niemeier, Kruetzer, & Taylor, 2005) and are usually able to transfer learning from remedial tasks to similar tasks (Neistadt, 1994).

Despite the need for effective cognitive rehabilitation, research to date is hardly encouraging, with little performance improvement directly attributable to treatment per se (Curran, 2004; Limond & Leeke, 2005). Furthermore, the current approach is non-standardised, largely atheoretical and unrelated to instrumental daily living activity (Wilson, 1997, 2003). Recently, Mateer (2003) argued that cognitive rehabilitation should be creative, eclectic, and functionally oriented, drawing on the broader field of psychology (Ownsworth & McKenna, 2004; Wilson, 1997, 2002). A neglected area in cognitive rehabilitation that could benefit the cognitively impaired is the process of skill acquisition. In the skill acquisition literature, goal-directed learning is modelled as a multiphase process characterised by qualitative and quantitative change. We argue that examining post-injury learning from this perspective is likely to be beneficial in assessing a patient's status (e.g., stage/level) and monitoring their progress, as well as identifying their changing needs over the course of learning. For example, the patient's performance could be assessed against change or improvement in the qualitative variables linked with different phases of skill acquisition such as attentional resource load, error frequency and type, speed and fluidness of execution, adaptability of strategies, efficiency of attentional allocation (e.g., eye gaze), and subjective experience. Operationalising and measuring these variables would also enable the modelling of inter-individual (or intra-individual) variability in the rate of skill acquisition in different types of tasks or types of impairment. Although the cognitive rehabilitation literature is concerned with overcoming a skills deficit (Robertson, 1990), the application of skill acquisition in this context is non-existent.

Skill acquisition research has been valuable in understanding and benchmarking performance in the non-impaired. For instance, research has shown that there is a changing ability–performance relationship over the course of skill acquisition such that (a) general ability is the best predictor of performance in the initial stage of skill acquisition, (b) there is an increasing, then decreasing relationship between perceptual speed ability and performance with practice, and (c) perceptual motor ability is the best predictor of performance in the final stage of skill acquisition (Ackerman, 1988). In addition, research has generated a number of practical guidelines for improving learning and instruction: (a) the increment in performance over practice will become progressively smaller over time; (b) proceduralised skills are retained longer than declarative facts; (c) breaking up complex skills into component skills and removing complexity in instructional material can assist in reducing attentional overload in the early phases of skill acquisition; (d) greater consistency in task components will improve automation; (e) training should involve a combination of declarative facts (passive) and procedural tasks (active); and (f) training should be as ecologically valid as possible because automation is relatively context-specific (Ackerman & Humphreys, 1989; Adams, 1987). Although useful to many learners, we propose that current models of skill acquisition need to be more inclusive; that is, capable of describing a more heterogeneous range of learners, including those living with some form of cognitive impairment. Thus, while those with ABI are likely to benefit from the integration of skill acquisition research in cognitive rehabilitation, the skill acquisition literature should likewise benefit from extrapolation to this context in the sense of building broader models that incorporate new variables that may affect skill acquisition in those with cognitive impairment.

The aim of the current work is to describe how traditional models of skill acquisition can be adjusted to accommodate the needs of those with ABI. Below, we (a) describe current skill acquisition models; (b) challenge the conventional notion of a continuous, uni-directional, model of skill acquisition; and (c) outline key variables that can be leveraged to facilitate skill acquisition following ABI such as emotion, implicit learning, metacognition, motivation, and strategies. Although the manipulation of these variables could potentially benefit all learners, our aim is to focus on their role in improving skill acquisition among the cognitively impaired.

Process of skill acquisition

Despite a wealth of research, there is confusion regarding the distinction between skill and ability. Skill is (a) learned, (b) acquired through practice or training, (c) goal-directed, and (d) organised (Proctor & Dutta, 1995), while ability is a general attribute of the learner that is brought to the task or a potential to perform (Carroll, 1993). The notion of skill does not imply "all or nothing": people may vary in their level of proficiency on a given task (Patrick, 1992). Furthermore, a given ability (e.g., verbal ability) may be relevant to more than one skill (e.g., essay writing, debating, negotiating) (Keil & Cortina, 2001).

Skill acquisition is the process of acquiring a skill that is linked to goal-directed action. Although skill acquisition is a form of learning, not all learning (such as the learning of some declarative facts) is linked to goal-directed action. Despite varying terminology, the process of skill acquisition has conventionally been represented as a hierarchical three-phase process that is related to practice, the assumption being that, with practice, skill acquisition is linear, forward-moving, and progressive, representing the transition from novice to expert (Figure 1). As shown in Figure 1, assuming a novel task, in Phase 1 performance is associated with high attentional demand and is slow and error-prone, because attention is directed toward learning, understanding the task, and formulating and testing strategies for performance. With practice, in Phase 2, there is a decrease in attentional demand and an increase in the speed and accuracy of performance as stimulus–response mapping is refined and strengthened and strategies are crystallised. In Phase 3, performance is fast, accurate, and impervious to interference as strategies become automated.

Although the three-phase model has generally been regarded as axiomatic, alternative, four- or five-phase models of skill acquisition have appeared in the literature (e.g., Anderson, Fincham, & Douglass, 1997; Dreyfus & Dreyfus, 1986). A comparison of alternative skill acquisition models is presented in Figure 2. As shown in Figure 2, despite divergence regarding the precise number of phases, there is consensus across all models that the first phase is error-prone, requiring effortful concentration, and that the last phase is fluid and effortless, requiring little concentration due to the progression to automated performance. The development of appropriate and accurate stimuli–response mapping is thought to occur somewhere in the middle, but the nature of this transition has been less consistent in the literature. Alternative phase models do not invalidate the three-phase model. Rather, the three-phase model is somewhat more parsimonious or crude than the four- or five-phase models, which provide more detail about change in the learner's performance over the course of skill acquisition. The three-phase model is concerned with the acquisition of a specific skill in a specific context, whereas the alternative models allow for the generalisation of skills (to a novel problem or setting) and the refinement of higher order skills (e.g., playing tennis) consisting of component skills (e.g., serving), which consist of finer component skills (e.g., throwing the ball to a certain height). Accordingly, the latter models may be more helpful in revealing diagnostic information about the learner's interaction with the task or the idiosyncrasies of task performance, for example error frequency and type, degree of difficulty, fatigue, forward and/or backward progression, strategies, etc.

Phase transition: Skill acquisition as a bi-directional process

A problematic element of any phase theory is the nature of the transition from one phase to the next. Current models (see above) can give the impression that skill acquisition is a continuous, linear, unidirectional process, with no "slipping back". However, we argue that this is an idealised representation. In reality, the boundary between each phase is likely to be fuzzy, and the transition from one phase to the next, gradual as opposed to categorical (VanLehn, 1996). Thus, the literature needs to be explicit in acknowledging interindividual variability in the rate of skill acquisition, specifically that skill acquisition is not always unidirectional and may be quite dynamic in its trajectory, involving reversion or slipping back to an earlier part of the same phase or even a previous phase ("phase slippage"). For instance, Siegler and Stern (1998) examined children's performance on an inversion arithmetic task (e.g., $20 - 15 + 15 =$) and found that although strategies tended to improve over the course of practice (e.g., recognising that subtracting and adding the same number cancelled that number out), there was also substantial reversion to inferior strategies.

Phase slippage is likely to be a common phenomenon among those with ABI due to interference caused by cognitive impairment (Evans et al., 2000; Tate, 1997). This could occur unpredictably and independently of the cognitive rehabilitation schedule or the learning task itself. For example, the most frequently diagnosed neuropsychological condition following ABI is impaired and/or deteriorating memory functioning (Tate, 1997). And, while skill acquisition in those with normal memory functioning is likely to follow the power law of practice (i.e., a steady increase in performance until asymptote performance is reached), in ABI interference caused by forgetting is likely to alter this process, making skill acquisition more discontinuous or irregular (Evans et al., 2000). Accordingly, we argue that skill acquisition should be modelled as a bi-directional, dynamic process, allowing for phase slippage. It is possible that phase slippage in the general population has been concealed in past research due to the method of data analysis; that is, aggregating data, regardless of ability level. A performance curve based on aggregated performance data is more

Task practice

	Phase 1* Cognitively involving phase where the learner must attempt to understand the task and what is required. Characterised by slow and error prone performance.	**Phase 2*** Formulation and refinement of strategies for successful performance. Reduction in error frequency, speed-up in performance.	**Phase 3*** Strategies become automated, leading to quick, accurate and effortless performance. Asymptotic performance is reached. Performance no longer susceptible to interference.
McGuire (1961)	Stimulus encoding	Mediation	Response learning
Fitts (1964); Fitts & Posner (1967)	Cognitive phase	Associative phase	Autonomous phase
Fleishman (1960, 1972)	Associated with broad content ability	Associated with perceptual-motor ability	Associated with task-specific ability developed over practice
Schneider & Shiffrin (1977)	Controlled processing	Mixed (controlled and automatic) processing	Automatic processing
Anderson (1982, 1983)	Declarative stage: Conscious knowledge	Knowledge compilation process converting knowledge to strategies	Procedural stage: Unconscious knowledge
Rasmussen (1983, 1986)	Knowledge-based performance: Performance dependent on thorough understanding of task	Rule-based performance: Performance guided by stored rule-base	Skill-based performance: Performance is smooth, automated, and highly-integrated
Norman & Shallice (1985)	Selection (component schemata): Selection and control of schemata by limited capacity executive system.	Activation (source schemata): Coordination and integration of component schemata. Reflexive triggering of hierarchically organised schemata	Action sequence development: Individual differences in rate of proceduralisation
Ackerman (1986, 1987, 1988)	Associated with general ability	Associated with perceptual speed ability	Associated with psychomotor ability
Kyllonen & Woltz (1989)	Working memory capacity and general declarative knowledge	Efficiency of processing	Procedural knowledge
Shuell (1990)	Initial phase: Acquisition of isolated information.	Intermediate phase: Inter-connection between each piece of information formed (knowledge is more abstract).	Terminal phase: Integrated knowledge structure. Autonomous functioning

*As described by Fitts & Posner (1967)

Figure 1. Comparison of the three-phase models of skill acquisition.

Three Phase Models	*Phase 1* • Understanding the task and its requirements	*Phase 2* • Formulating and refining strategies for successful performance		*Phase 3* • Strategies become autonomous, leading to quick, accurate and effortless performance	
Anderson et al. (1997)	*1. Analogy* • Analogical extension of example to new problem	*2. Abstract Rule Generation* • Consciously identify rule associated with problem and apply it	*3. Production Rule Generation* • Procedural embodiment of rule is developed	*4. Example-based Rule Generation* • Specific example retrieved to match target problem	
Haring, Lovitt, Eaton, & Hansen (1978)	*1. Acquisition* • Just beginning to learn the skill • Can't perform task reliably or accurately	*2. Fluency Building* • Accurate response to learning task • Task performed slowly, haltingly	*3. Generalisation* • Accurate and fluent in responding • May fail to apply skill to new situation or setting	*4. Adaptation* • Fluent and accurate in skill • Skill applied to novel situation or setting without prompting	
Dreyfus & Dreyfus (1986)	*1. Novice* • Recognise task features • Acquire rules based on features • 'Context free' processing	*2. Advanced Beginner* • Marginal performance improvement • Learn more sophisticated rules • Situational factors influence rules	*3. Competent* • Organised strategies simplify and improve performance • Goal setting	*4. Proficient* • Use past experience to perform and anticipate outcomes • Use of intuition (automaticity)	*5. Expert* • Perform without awareness • No conscious decision making • Do what 'normally works' • Holistic processing
Synthesis of Dave (1975) & Simpson (1972)	*1. Imitation/Guided Response* • Observe skill and try to repeat it OR • Attempt to follow a model or set criteria	*2. Manipulation/ Mechanism* • Can perform with a certain level of competence and efficiency	*3. Precision* • Skill reproduced with accuracy, proportion and exactness • Performance independent of original source	*4. Articulation/Complex Overt Response* • Skill combined in sequence with harmony and consistency	*5. Naturalisation/ Adaptation* • Skill performed with ease and automaticity • Motor activity altered to meet specific demands of task

Task practice →

Figure 2. Correspondence of alternative models with the three-phase model of skill acquisition.

likely to be smooth and to follow the power law of practice (even if individual performance data do not follow this pattern), thus obscuring individual differences in skill acquisition (Haider & Frensch, 2002).

Improving skill acquisition in ABI: Role of emotion, implicit learning, metacognition, motivation, and strategies

Not all learners are compliant or enthusiastic about skill acquisition nor may they find the task of acquiring a new skill to be an engaging, pleasant experience. This may be particularly so among those with ABI, for whom life is often difficult with numerous obstacles to surmount each day, even without the added pressure of having to learn or relearn skills. Past research on skill acquisition has overemphasised the role of cognitive ability in task performance (e.g., general ability, perceptual speed ability, psychomotor ability), despite evidence for cognitive and non-cognitive variability (e.g., Schmidt, Kleinbeck, & Brockmann, 1984). This is problematic, given that cognitive ability (or in the case of ABI cognitive impairment) cannot be easily leveraged to improve the rate and quality of skill acquisition. Thus, we suggest that variables such as emotion, implicit learning, metacognition, motivation and strategies that can be leveraged to assist learning and performance should be incorporated in skill acquisition models. Such variables should help people acquire skills either more quickly or in a more engaging, enjoyable manner.

Emotion

People with ABI often demonstrate a response pattern that is similar to insecure attachment in children; that is, they appraise the environment as threatening (e.g., hostile, unmanageable, unpredictable) and tend to abandon or avoid activity that is too difficult (Ducharme, 2003). Since the 1980s, a great deal of research has been devoted to understanding the link between cognitive appraisal and emotion (e.g., Averill, 1982; Frijda, 1986; Oatley & Johnson-Laird, 1987; Ortony, Clore, & Collins, 1988; Scherer, 1984; Smith & Ellsworth, 1985; Weiner, 1986). According to this paradigm, people engage in a "meaning analysis": an evaluation of the relationship between themselves and the environment and its significance for wellbeing. The assumption is that change in cognitive appraisal is systematically related to change in emotion. Given this assumption, we might predict a strong relationship between one's cognitive appraisal of the task environment and emotional state. For example, those who are performing well are likely to appraise the task environment as enjoyable and to experience positive affect (e.g., happiness, pride), whereas those who are performing poorly are likely to appraise the task environment as stressful and to experience negative affect (e.g., sadness, frustration). Indeed, McGrath and Adams (1999) found that negative affect was a common response to ABI: goals that were previously attained quickly and easily that were difficult to attain after injury became associated with frustration, and goals that were perceived as unattainable after injury became associated with sadness.

A learner's emotional state is likely to affect the amount of attention that is invested in task performance, thus influencing skill acquisition and performance. For instance, high self-focused attention associated with chronic negative affect may intrude into consciousness and interfere with information processing (Ellis & Ashbrook, 1988). In contrast, positive affect may facilitate information processing (Smith & Ellsworth, 1987) so that a person is able to achieve automation and asymptote performance more quickly (Wood, Saltzberg, & Goldsamt, 1990). Accordingly, emotional stability is likely to play a key role in the success of skill acquisition. In particular, it is important to avoid demoralisation and demotivation (Ownsworth & McKenna, 2004). Ducharme (2003) argued that greatly reduced or simplified learning criteria should reduce the probability that the task environment will overwhelm the patient. He advocated the use of success-based learning and systematic graduation among those with ABI to develop a secure foundation for task performance. The patient is initially rewarded for successful performance on a task that he or she is able to easily master. The patient is then exposed to successively greater demand at a pace that is slow enough for him/her to manage comfortably, with behavioural support gradually reduced over time. Within this tolerance-building process skill acquisition is safe thereby reducing threat appraisal, and subsequent negative affect, and promoting cooperation and perseverance.

Despite the obvious link between emotion and skill acquisition, skill acquisition research has (in large part) progressed with little attention to this variable. The underlying cause of this dissociation may stem from the emphasis placed on the computer metaphor of "human information processing", which has been noticeable in its failure to accommodate the role of emotion in learning and task performance. If emotion is a determinant of information processing, then a revision of current skill acquisition models to include the role of emotion at each phase is not only appropriate but necessary (Langan-Fox, Armstrong, Anglim, & Balvin, 2002).

Implicit learning

As mentioned earlier, impaired and/or deteriorating memory functioning is prevalent in ABI (Tate, 1997). A common feature is impaired declarative (explicit) memory versus persevered procedural (implicit) memory. A basic assumption in the skill acquisition literature at present is that the primary determinant of interindividual variability in performance is practice (i.e., trial-and-error learning). However, we would argue that this is an oversimplification when dealing with the memory-impaired. Trial-and-error learning is problematic for those with impaired explicit (or error correction) memory and preserved implicit memory because implicit learning is susceptible to interference from error (Baddeley & Wilson, 1994). Thus, learning and instruction in this population should capitalise on implicit learning, particularly in the early phase of skill acquisition where declarative knowledge is important. Baddeley and Wilson (1994) argued that errorless learning, in which information is introduced so as to avoid or significantly reduce error frequency, should minimise interference and thus maximise implicit memory performance. Komatsu (1999) found that errorless learning facilitated skill acquisition in the context of daily functioning following ABI. Evans et al. (2000) found that those who were more severely memory impaired benefited more from errorless learning than those who were less severely memory impaired when the interval between learning and recall was relatively short and learning was tested so as to facilitate the retrieval of information from implicit memory.

Although there is some evidence to suggest that errorless learning is superior to trial-and-error learning for people with amnesia, it is unclear whether it is beneficial for skill acquisition outside of memory impairment. Notably, errorless learning has found wide application in the congenital learning disability literature (Evans et al., 2000). Obrzut and Hynd (1987) commented on the similarity between learning difficulty in ABI and congenital learning disability. However, it is unclear as to whether learning disability is associated with a cognitive deficit or simply slower learning (Kulak, 1993).

Metacognition

ABI is frequently characterised by impaired self-monitoring and self-regulation. This is problematic for skill acquisition given that a person's knowledge or understanding of how much progress is being made is a key driver of performance. The term "metacognition" is used to describe an individual's awareness of his or her cognitive functioning, including attention, conjecture, fantasy, knowledge, and memory (Wellman, 1985). Ownsworth and McKenna (2004) advocated the use of self-awareness training to enhance metacognition in ABI. In this context, metacognition can be operationalised as an individual's awareness of his or her deficit(s) in cognitive functioning. Such awareness should facilitate self-monitoring and self-regulation during skill acquisition, including the development of appropriate compensatory strategies. Furthermore, there is evidence to suggest that metacognition can assist the generalisation and transfer of learning to instrumental daily living activity (Ownsworth & McKenna, 2004). Ownsworth and McFarland (1999) investigated the remediation of memory impairment in an ABI population using a diary approach versus a metacognitive approach focusing on promoting self-awareness. They found that the metacognitive approach received a more positive rating of treatment efficacy and was associated with superior memory performance. For those with ABI, metacognition, and the subsequent use of compensatory strategies, is likely to be an important variable throughout the skill acquisition process.

Motivation

ABI is often associated with motivational loss either as a direct result of injury, or as a result of the patient's psychological reaction (e.g., agitation, anxiety, depression, frustration) to injury (Ownsworth & McKenna, 2004). In addition, those who were not in the habit of setting explicit goals before injury often find it difficult to do so after injury and, as such, goal setting is frequently marked by difficulty, frustration, and self-doubt (Siegert, McPherson, & Taylor, 2004). This is problematic, given that motivation is likely to have a profound impact on skill acquisition (Marin & Chakravorty, 2005). For instance, the manipulation of motivation through setting specific, difficult goals has consistently been shown to improve task performance (Kanfer & Ackerman, 1989; Locke, 1965; Locke & Latham, 1991; Mun & Kun, 2004; Schmidt et al., 1984; Wood, Mento, & Locke, 1982; for a review see Locke & Latham, 2002), particularly in those with lower ability (Kanfer & Ackerman, 1989).

Given the breadth and diversity of the goals literature, Siegert et al. (2004) argued that research on goal setting should be readily generalisable to a cognitive rehabilitation setting. Furthermore, there is substantial research in the goals literature to support the use of goal setting as an effective tool for behavioural change (Siegert et al., 2004). There is some evidence to support the efficacy of motivational training in ABI (Ownsworth & McKenna, 2004). For instance, research has shown that goal setting is an important determinant of strategy implementation

(Tate, 1997) and treatment outcome (Siegert et al., 2004). Incorporating the patient's perspective in goal setting is also likely to be important (Siegert et al., 2004).

We suggest that motivation may go some way in compensating for impaired cognitive functioning in skill acquisition. However, it is also possible that cognitive functioning may place a ceiling on task performance. Indeed, many have argued that a person cannot do something through sheer will power alone (Tubbs, 1994; Vroom, 1964; Yeo & Neal, 2004). Thus, although those with cognitive impairment and high motivation may outperform those with cognitive impairment and low motivation (Kanfer & Ackerman, 1989; Locke & Latham, 2002; Vroom, 1964), it is possible that there is less scope for compensation as those with ABI reach a ceiling imposed by their cognitive impairment.

Strategies

Over the course of skill acquisition, people adopt different strategies for performance, with some being more or less optimal (Lee, Anderson, & Matessa, 1995). In fact, one study found that strategies accounted for 88% of the variance in performance (Lee et al., 1995). ABI is not only associated with cognitive impairment (for which compensatory strategies are needed), but also with impaired ability to generate or implement effective strategies for performance (Tate, 1997). In a study of memory impairment following ABI, Tate (1997) found that those who used strategies spontaneously did not demonstrate an advantage on a memory-based performance task over those who did not use strategies spontaneously, presumably because their strategies were suboptimal. In contrast, Dirette (2004) compared the use of strategies for attention and processing in those with and without cognitive impairment and found that although strategy use was significantly higher among those without cognitive impairment, chunking and verbalisation were the most frequently used strategies regardless of cognitive functioning. Dirette (2004) concluded that although those with ABI used strategies to a lesser extent, they used strategies in a way that was very similar to people in the general population. Notably, perceived task difficulty corresponded with perceived difficulty of strategy generation and implementation in this study. Further research is needed to clarify the prerequisite criteria for strategy self-generation and implementation following ABI.

Oddy and Cogan (2004) suggested that strategy use following ABI is likely to be affected by anxiety, depression, and knowledge of potential strategies. In addition, there is a link between metacognition and strategy use in both ABI and the general population (Dirette, 2004). Although some people with ABI may be unable to generate or implement strategies independently, the provision of guidance about which strategies to use, along with training in their implementation, could facilitate the use of optimal strategies in this population, serving as a remedial step in the intermediate phases of the skill acquisition process.

Conclusion

Although the cognitive rehabilitation literature is concerned with overcoming a skills deficit (Robertson, 1990), the application of skill acquisition research in this context has been non-existent. Examining post-injury learning in terms of change or improvement in the qualitative variables linked with different phases of skill acquisition (e.g., attentional resource load, error frequency/type, speed/fluidness of execution, adaptability of strategies, efficiency of attentional allocation, subjective experience) is likely to be beneficial in assessing a patient's status (e.g., stage/level) and monitoring their progress, as well as identifying their changing needs over the course of learning. However, current models of skill acquisition have overlooked the potential impact of variables such as emotion, implicit learning metacognition, motivation, and strategies that can be leveraged to improve skill acquisition. We argue that such variables should be incorporated in skill acquisition models and carefully monitored during the skill acquisition process. The current paper attempted to lay the groundwork for modelling and improving skill acquisition in ABI. Specifically, we proposed that (a) skill acquisition should be modelled as a bi-directional process, allowing for phase slippage; (b) cognitive appraisal of the task environment should be managed throughout the skill acquisition process to avoid interference with information processing due to negative affect; (c) learning and instruction should capitalise on implicit learning, particularly in the early phase of skill acquisition where declarative knowledge is important; (d) metacognitive training can be used to enhance skill acquisition by improving self-monitoring and self-regulation and hence the use of compensatory strategies; (e) improving motivation through goal setting may go some way in compensating for cognitive impairment; and (f) training should be used to promote knowledge of optimal strategies and how to implement them effectively. Future research should aim to improve the generalisability and veracity of skill acquisition research, particularly for the cognitively impaired, by incorporating the aforementioned variables in skill acquisition models.

This article is the first substantive attempt to link skill acquisition research to ABI. As such, it has potential application in the development of a multidisciplinary approach (human factors, behavioural neuroscience) to cognitive rehabilitation. Applying skill acquisition models in this context has the potential to enhance short- and long-term quality of life among those with an ABI through improved learning, self-care, and independent living.

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