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The use of errorless learning in the rehabilitation of Action Disorganisation Syndrome: a case study

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Abstract

This case study investigates the use of errorless learning in the rehabilitation of action disorganisation syndrome (ADS). Case DL suffered 2 traumatic brain injuries to the frontal lobes (2002 and 2010) and presents with a clear case of ADS. DL displays high levels of disorganisation when engaging in sequential tasks. Errorless learning was used in an attempt to rehabilitate abilities in two everyday routine sequential actions; making a cup of tea and making toast with butter and jam. Errorless learning involves the deliberate prevention of errors using both verbal and physical prompts. The intervention resulted in a significant decline in the number of errors made in both tasks, showing errorless learning as an effective method for rehabilitation in everyday action.

Introduction

Action disorganisation syndrome (ADS) is a term used to describe a deficit of action that is not related to motor abilities (Schwartz, 1995). It is an anatomically neutral term used by several researchers due to the blurred distinction between two closely related neuropsychological syndromes. The first is ideational apraxia, traditionally associated with left hemisphere damage, although the specificity of this has been challenged (Buxbaum, Schwartz, & Montgomery, 1998). The second is frontal apraxia, due to prefrontal lesions. In both of these syndromes patients display a high amount of disorganisation when carrying out sequential tasks; displaying an inability to plan and execute the complex sequence of motor actions involved in the usage of tools or objects in everyday life (Duncan, 1986; Lehmkuhl & Poeck, 1981).

Everyday action

The ease with which most of us are able to conduct everyday routine sequential actions such as making a cup of tea, toast, or getting dressed, can lead us to believe that we rely on little cognitive processing to do so. Whilst we may require a small amount of conscious concentration for these tasks, the ability to carry out these actions actually relies on a complex coordination of a number of psychological processes. These include working memory; which is vital for keeping track of the task, semantic memory for the knowledge of object usage, attention, and the coordination of perceptual and motor skills (Botvinick & Plaut, 2004). Also integral to the success of such tasks is the ability to retrieve stored knowledge about the sequential order of the task (Morady & Humphreys, 2011). Patients with ADS often present with a great difficulty in carrying out routine actions due to distinct impairments in the processes involved.

Importance of the frontal lobes

Research has indicated the importance of the frontal lobes in tasks of everyday action. Stuss (2011) reviewed a series of papers that reported impairments with attention as a result of frontal lesions. Seven basic task types were identified; sustaining, concentrating, shifting, suppressing, switching, preparing, and setting. After brain injury to the frontal lobes, the ability to utilize these abilities can become impaired. Stuss (2011) states that there is no central executive within the frontal lobes, as executive functions represent only one category of functioning. Instead, Stuss identifies four: energisation, executive functioning, self-regulation and metacognition. Energisation refers to the ability to initiate and sustain a response, which after superior medial damage can become impaired (Alexander, Stuss, Picton, Shallice, & Gillingham, 2007; Shallice, Stuss, Alexander, Picton, & Derkzen, 2008; Shallice, Stuss, Picton, Alexander, & Gillingham, 2008). Stuss identifies executive functioning as involving two processes; monitoring, which is associated with right lateral damage and task setting which is associated with left lateral damage (Picton, Stuss, Shallice, Alexander, & Gillingham, 2006; Stuss, Bins, Murphy, & Alexander, 2002). Self-regulation is associated with the ventromedial cortex, after damage to which can produce impairment in the ability to integrate motivational, emotional and social aspects of behaviour, along with risk/reward judgement (Bechara, Damasio, Damasio, & Lee, 1999). The final category of frontal lobe functioning that Stuss identifies is metacognition, which refers to higher order functions that coordinate all other frontal capacities. Thus, patients with ADS often

experience losses in some or all of these functions, resulting in marked disorganisation when carrying out every day routine sequential actions.

“Slips of action”

“Slips of action” refer to absent-minded mistakes that are made when one is distracted or preoccupied. These errors often occur at “branch points” or “decision points” of a task sequence (Reason, 1990). This is when the environmental context bears some resemblance to another context, resulting in an action instantaneous to the latter. Reason (1990) offers the example of making ones way to the car through the back door, and accidentally putting on wellington boots and a gardening jacket as if one was about to do work on the garden. Hence, the behavioural and physical contexts are similar, resulting in a branch point error. Findings show a spectrum of action disorganisation from slips of action in normal subjects, to highly disorganised behaviour in patients with ADS (Schwartz Montgomery, Buxbaum, Lee, Carew, Coslett, Ferraro, & Fitzpatrick-DeSalme, 1998; Schwartz, Reed, Montgomery, Palmer, & Mayer, 1991). Disorganisation within the spectrum begins at the between task level (branch points), with disorganisation becoming apparent at the within-task level in ADS as severity increases. Other errors people tend to make are perseverations (repeating a particular stage of some task), omissions (forgetting part of a task) and intrusions (of a similar or unrelated context) (Reason, 1948).

After brain injury, retrieval of information about routine actions is sometimes lost, along with the ability to inhibit already completed actions and to organise actions sequentially (Forde, Humphreys, & Remoundou, 2004; Humphreys and Forde, 1998; Schwartz & Buxbaum, 1997). This results in an inability to carry out everyday actions successfully, and subsequently patients produce an abnormally high number of errors.

Schwartz et al. (1991) propose that the errors made by ADS patients can be separated into two main categories; one concerned with the processing of a task sequence, and the other with omissions or incorrect usage of objects. The former may involve: perseverating on a particular step of the task already completed, omitting a step in the task sequence, or performing the sequence in an incorrect order. The latter category of errors may involve semantic errors such as, using a spoon to spread jam on toast or using a finger to stir tea. Schwartz et al. (1991) suggests that errors of omission in ADS are due to a weakening of top-down activation within the schema hierarchy whereas perseverative errors are thought to be due to insufficient lateral inhibition.

Both non-brain damaged individuals and ADS patients tend to commit the same kinds of errors in everyday action (Bickerton, Humphreys and Riddoch, 2006). However, patients with ADS commit errors even when they are paying close attention to the task, whereas non brain-damaged individuals tend to commit errors when they are not attending to the task. ADS patient’s errors are also more blatant, often remain uncorrected and they are not always able to acknowledge their errors, even when they have been pointed out to them (Schwartz, 1995; Humphreys, Forde and Riddoch, 2001; Hart, Giovannetti, Montgomery, & Schwartz, 1998).

Schwartz et al. (1991) noted that patients with ADS show a tendency to abandon certain subtasks before the ultimate goal is completed and show much fragmented behaviour.

They also noted that ADS patients spend a great deal of time “toying” with objects. Botvinick and Plaut (2004) noted this as independent actions in their paper. These are actions that are unnecessary for the completion of the goal, for example, picking up a packet of sugar, shaking it, and placing it down again in order to eat eggs at breakfast.

Botvinick and Plaut (2004) created a computer simulation for the task of making a cup of coffee and found that errors tended to occur at branch points, which is synonymous with empirical findings. Also consistent with other findings were the occurrence of omission, sequencing and perseverative errors. There were also intrusions as a result of context confusion, for example, after picking up the spoon the model sometimes moved directly to stirring, rather than moving towards the sugar. This study focuses heavily on the qualitative patterns of errors made i.e. the behavioural coding of mistakes, rather than quantitative errors which is the main focus in the rehabilitation of everyday action in ADS. Botvinick and Plaut’s study gives a complicated analysis of the types of errors that are made in order to address the sufficiency of a recurrent connectionist approach to routine sequential action. Recurrent connectionist networks suggest that knowledge is acquired through exposure to the task instead of there being a mirrored structure between the task itself and the processing system (Elman, 1990).

Attempts to rehabilitate

There is much research on the coding of errors in ADS but considerably little on the rehabilitation of everyday action in ADS. When attempting to rehabilitate everyday action in ADS one needs to take into consideration the patient’s inability to monitor and correct errors, along with their lack of insight to errors made. The many cognitive processes involved in everyday action and the complex interactions between them can be damaged in a variety of ways in patients, which poses a great difficulty in rehabilitation (Forde and Humphreys, 2002).

Donkervoort, Dekker, Stehmann-Saris, & Della Sala (2001) examined the effects of “strategy training” on left hemisphere stroke patients presenting with apraxia. Patients were taught to self-verbalise their actions to support performance in activities of daily living (ADL). The effects were found to be more beneficial than standard occupational therapy which focuses more on the improvement of sensory and motor abilities in the patient. However, the effects were relatively small and of short term benefit. Patients with more severe apraxia showed less improvement in ADL functioning. This displays the need for an alternative strategy for those with a greater severity of impairment. Another point to consider is that, following brain injury, the capacity for comprehending language is also sometimes diminished. In these instances verbalisation strategies are likely to be of little benefit.

Bickerton et al. (2006) attempted to rehabilitate the ability to make a cup of tea in a patient (FK) who presents with a clear case of ADS. Previous attempts to rehabilitate FK’s performance in everyday routine actions proved unsuccessful. Efforts included using written instructions to guide the patient’s actions and physically copying the experimenter’s actions throughout the duration of the task (Forde & Humphreys, 2002). The lack of success may reflect FK’s severe deficits in the executive aspects of working memory, which prevents the correct order of a sequence from being performed (Forde et al., 2004). Bickerton et al. (2006) used a verbalisation strategy in an attempt to

bypass some of FK's cognitive limitations, whilst concentrating on his intact abilities in verbalisation. There were some beneficial effects immediately after training; however effects did not expand across training sessions. Success relied heavily on the application of the poem which was less successful, as FK would often forget to do so. They concluded that additional strategies were needed to target this. They found no generalisation to other tasks which is unsurprising considering the specificity of the poem content. Again this study highlights the need for a different sort of strategy for those with severe impairments, including issues with memory and language.

Goldenberg and colleagues used "maximal support training" in patients with ideational apraxia (Goldenberg, Daumuller, & Hagmann, 2001; Goldenberg & Hagmann, 1998). These patients show poor understanding for the purpose of single objects and difficulties in conducting routine everyday actions. Maximal support training involves the therapist leading the patient through a set of single object actions and guiding the patient through the stages of a task in order to complete the activity. Performance improved on trained actions but did not extend to other actions that were untrained. Again this is relatively unsurprising considering the specificity of tasks and of course the impairment of brain functioning in patients. Success on trained actions suggest that a more procedural way of learning, as opposed to a more declarative approach taken with verbalisation techniques, may be more beneficial in the rehabilitation of everyday action.

Errorless Learning

Similar to maximal support training is the errorless learning technique, first introduced by Terrace (1963). Both provide full support from the experimenter throughout the task. However, errorless learning specifies the deliberate prevention of errors which maximal support training does not. Errorless learning is a teaching technique whereby the learner is not given the opportunity to make any errors whilst learning new information or procedures. It is recommended for use in schooling, particularly for students who have suffered a TBI and/or those who have severe specific memory problems. It has been found that when students with memory problems make errors, there is a high likelihood that that information will become part of their memory (Ylvisaker, Hibbard, & Feeney, 2006). This risk is eliminated with errorless learning.

Kessels and Haan (2003) conducted a meta-analysis of memory rehabilitation techniques based on intact implicit learning capacities in amnesic patients. Errorless learning was found to have a large and significant effect size compared to other implicit memory techniques such as the vanishing cues method which had small effect sizes and insignificant results.

Further support comes from Wilson, Baddeley, Evans and Shiel, (1994) who carried out six experiments on the use of errorless learning in the rehabilitation of memory impaired participants. The first involved amnesic patients and controls, who were required to learn two word lists. One list was learnt using errorful learning whereby guessing was permitted, resulting in some incorrect answers. The other list was learnt using errorless learning which permitted correct answers only and no guessing. Participants performed far better when using the errorless learning technique. The remaining five experiments were single case studies of patients with severe memory impairments. Tasks related to information needed in everyday life, including naming objects and people, and learning

new items of general knowledge. In each task errorless learning produced superior results to errorful learning.

This study focuses on the rehabilitation of two everyday routine sequential actions (making a cup of tea and making toast with butter and jam) in a single case; DL. DL presents with an extreme case of ADS and displays high levels of frontal lobe dysfunction. He shows impairments in all four categories of frontal lobe functioning identified by Stuss (2011). It would not be possible to use any sort of verbalisation strategy due to his marked language difficulties; DL understands some simple commands but not complex questions. He has significant receptive and expressive aphasia and gives inconsistent yes/no responses. This was confirmed by the Putney Auditory Comprehension Screening Test (PACST) where he scored only at chance level (31/60) (Beaumont, Marjoribanks, Flury, & Lintern, 2002). Questions include “*Is your name...?*” and also more obscure questions such as “*Do hedgehogs build roads?*” Other tests that give insight to the level of his difficulties include the Token’s Test in which DL scored a poor 14/120 (McNeil and Prescott, 1978). Here the patient is required to point to a series of colours (blue/red/green/yellow/white), shapes (triangle/circle/square) and/or sizes (small/large) on command. On the Category Specific Names Test DL scored 14/120 when asked to match pictures of objects with their names, showing a marked impairment in semantic knowledge (Mckenna, 1997). DL’s typical spontaneous language is perseverative along with his behaviour. Another factor that makes communicating with DL difficult is that English is his second language. DL’s first language is Urdu.

We propose that errorless learning will be an effective method of rehabilitation for case DL as this technique will rely heavily on procedural learning, which may be a spared intact ability of his. During the errorless learning intervention, DL will be both verbally and physically prompted in order to aid the correct execution of each sequence in the task.

Errorless learning bypasses his impaired capacities with language which other studies that use verbalisation techniques such as Donkervoort et al. (2001) rely on functioning properly. DL does not have the memory capacity to learn a poem as used in Bickerton et al.’s (2006) study. It was not possible to conduct any neuropsychological tests that focus on memory functioning due to his level of impairment. DL’s deficit with language should not be an issue in this study as he will be given a command at the beginning of the session e.g. “Make a cup of tea with milk and sugar” and be presented with all relevant objects which will provide a visual cue to the accompanying command.

The structure of this experiment is in-part taken from Bickerton et al. (2006) who looked at the rehabilitation of the ability to make a cup of tea in case FK. Separate stages were used for baseline measures, intervention and follow up. Extra stages were used for the learning of a script to aid performance which this study does not incorporate. This study will add a delayed follow up stage to investigate any long term effects of errorless learning.

Hypotheses: We predict that the use of errorless learning in the rehabilitation of two everyday tasks will significantly reduce the amount of errors made. We also predict that

the effects will not be long-lasting; the numbers of errors are likely to return to near baseline levels after a considerable delay following the removal of errorless learning. Therefore we predict that errorless learning will need to be an on-going form of treatment for rehabilitation.

Method

Design

The use of errorless learning in the rehabilitation of action disorganisation syndrome was investigated using a single-case experimental design. The research focused on a single case, DL, rather than a group of participants. The study used multiple baselines to investigate whether the introduction of an errorless learning technique aided the rehabilitation of two everyday tasks; making a cup of tea and making toast with butter and jam.

Participants: Case DL

DL (not actual initials) is a 43-year-old man who suffered a traumatic brain injury on the 8th December 2010. He had a previous head injury in 2002, after which he developed epilepsy, which up to the point of his second brain injury was poorly controlled. The second head injury caused an acute right frontal intraparenchymal bleed and a small amount of subarachnoid blood with intraventricular extension. DL demonstrates a high level of disorganisation when attempting to carry out everyday tasks, thus he displays; action disorganisation syndrome (Schwartz, 1995).

Patient DL does not have the mental capacity to give written consent to this research; therefore a member of his family – and legal guardian - consented for him. This family member was also given a debrief sheet with the researchers contact details should they wish to remove DL or any data from the study. DL was given the opportunity to refuse participation during each session and data was not collected on these days. Confirmation from the Clinical Neuropsychologist at Frenchay Brain Injury Rehabilitation Centre for usage of the data has also been obtained in writing.

Materials

Materials used for the task of making a cup of tea were; a kettle, water, a mug, teaspoon, container of sugar, a small plate to put used teabag and a carton of milk. The materials used for the task of making two pieces of toast with butter and jam were; a toaster, packet of bread, a tub of butter, a jar of jam, a plate and a knife. A record sheet was also used for each individual task carried out in order to record the number and types of errors made.

Procedure

The following stages of experimentation are relevant for both the tea and toast making tasks. The start times for each activity varies as the toast task was started 7 weeks after the tea making task which was in the follow up stage of experimentation (stage three).

Stage One: Baseline – Tea (sessions 1 - 10); Toast (sessions 1 - 17).

Baseline measures were taken during the first 10 tea making sessions and first 17 toast making sessions. Task relevant objects were presented to DL on a table he sat at. He was then instructed to “make a cup of tea with milk and sugar” or “make two pieces of toast with butter and jam”. Prompts were given during this stage however no corrections were given to errors made. Prompts included encouragement to continue with the task and for the correct execution of the next stage. Prompts were therefore coded as an error. It was sometimes necessary to give prompts to continue in order to complete the task.

Stage Two: Errorless Learning– Tea (sessions 11 – 18); Toast (sessions 18 – 25).

During this stage an errorless learning trial was administered followed by another trial whereby only prompts were given if necessary. Task relevant objects were presented to DL on a table he sat at. He was instructed to “make a cup of tea with milk and sugar with my help” or “make two pieces of toast with butter and jam with my help”. During this errorless learning trial DL was unable to make any mistakes due to quick intervention. For example, if DL reached for the wrong object his hand was interrupted and directed to the correct object. Verbal instruction was also given in order to direct DL to the next correct step of the task and to stop perseveration at any stage. After the execution of this first task, DL was then instructed to “make another cup of tea with milk and sugar without my help” or “make two more pieces of toast with butter and jam without my help”. The participant was observed and the number and types of errors made were recorded. Any prompts given in order to complete the task were coded under the appropriate category of error.

Stage Three: Follow up– Tea (sessions 19 – 28); Toast (sessions 26 – 35).

Task relevant objects were presented to DL on a table he sat at. He was then instructed to “make a cup of tea with milk and sugar” or “make two pieces of toast with butter and jam”. During the follow up stage no training or corrections were given. Prompts were given if necessary in order to complete the task and were coded under the appropriate category of error.

Stage Four: Delayed follow up– Tea (sessions 29 – 37); Toast (sessions 36 – 43).

Approximately two months after the administration of the final task, DL was again assessed on both of the tasks. No additional training was given. He was presented with task relevant objects and instructed to “make a cup of tea with milk and sugar” or “make two pieces of toast with butter and jam”. This was in order to investigate whether any effects from the errorless learning trials were still apparent after a long delay.

Performance Measures

The numbers of errors made during each task were recorded. These were coded under six different categories of error. The number of prompts needed were also recorded and coded under the appropriate category of error. The types of errors were in part taken from Bickerton et al. (2006) who categorised errors into content (correct execution of step and correct use of object), sequence, perseveration and additional errors. This

study categorises errors into 6 areas in order to address more distinct differences in the types of mistakes made. They are as follows:

Omission: The omission of a particular step. If a prompt was needed for the execution of a particular step this was also coded as an omission error.

Sequence: Incorrect sequence of a particular step was coded as a sequence error.

Semantic: Incorrect usage of an item was coded as a semantic error, for example, drinking the tea with a spoon.

Perseveration: Preservation errors include adding more than one teabag, too many spoonfuls of sugar, stirring the tea for long periods of time and spreading butter/jam on toast for long periods.

Addition: Addition errors were coded when any unnecessary step was conducted, for example scooping up breadcrumbs from the table and eating them.

Quality: Quality errors included using the wrong quantities of materials, e.g. butter, jam, water and milk.

It was decided between two experimenters what kinds of errors should be categorised under each sub-section. For the first few sessions two experimenters were present. Results were compared and any discrepancies discussed and resolved.

Results

The amount of autocorrelation for each stage of experimentation was calculated to rule out the possibility that each observation could be correlated with the next i.e. a gradual decline in errors over the course of time due to some practice effect and therefore not due to any intervention. The intervention stage was predicted to show some autocorrelation due to the nature of its predicted course of a decline in errors over time. This stage showed a significant amount of autocorrelation for the tea data $r = .68$, $p = .02$, and a marginally significant result for the tea data $r = .54$, $p = .07$. The follow-up stage of the tea data also showed a marginally significant amount of autocorrelation; $r = .5$, $p = .07$. All other stages of experimentation for both the tea and toast data showed no significant amount of autocorrelation; baseline tea; $r = .21$, $p = .45$, baseline toast; $r = -.01$, $p = .97$, follow up toast; $r = -.25$, $p = .36$, delayed follow up tea; $r = -.37$, $p = .198$, delayed follow up toast; $r = .18$, $p = .55$.

A Mann-Whitney U test was conducted to establish whether there was a significant difference in the number of errors obtained at each stage of experimentation. All calculations are two-tailed, unless otherwise stated. With reference to the data on making, tea the results show a significant difference between the baseline and intervention stages; $z = -3.58$, $p < .001$, baseline and follow up; $z = -3.56$, $p < .001$ and intervention and follow up; $z = -2.57$, $p = .01$.

The results for the data on making toast also show a significant difference between the baseline and intervention; $z = -3.99$, $p < .001$, baseline and follow up; $z = -4.31$, $p < .001$ and intervention and follow up; $z = -2.8$, $p = .005$.

Mann Whitney U tests were also computed for the delayed follow up stages compared with all other stages. The significant results are as follows: tea baseline and follow up $z = -3.7, p < .001$, tea follow up and delayed follow up $z = -3.75, p < .001$, toast baseline and follow up $z = -2.98, p = .003$, toast intervention and follow up $z = -2.967, p = .003$, toast follow up and delayed follow up $z = -3.63, p < .001$. There was one insignificant difference between the intervention and the delayed follow up for the tea data; $z = -1.6, p = .109$.

A Pearson correlation coefficient was computed to examine the relationship between the number of errors made at each observation and the course of time. With reference to the tea data there was no significant correlation during the baseline measure; $n = 10, r = -.46, p = .18$, follow up measure; $n = 10, r = .53, p = .12$, or delayed follow up measure; $n = 9, r = -.45, p = .23$. A significant negative correlation was found during the intervention phase; $n = 8, r = -.91, p = .002$. The toast data showed similar results with no significant relationship in the baseline; $n = 17, r = .05, p = .86$ or follow up stage; $n = 10, r = .44, p = .21$. There were significant negative correlations during the intervention stage; $n = 8, r = -.97, p < .001$ and delayed follow up stage; $n = 8, r = -.81, p = .02$.

Using the Fisher r-to-z transformation, the significance of the difference between correlation coefficients was calculated to show that the pattern of errors is different in each stage of observation. The tea data showed an marginally significant result between the baseline and intervention stages when using a two-tailed test of significance; $z = 1.79, p = .07$, but showed a significant result when using a one-tailed test; $z = 1.79, p = .04$. The remaining calculations were all significant when using a two-tailed test; tea intervention-follow up; $z = 3.64, p < .001$ and tea baseline-follow up; $z = 2.03, p = .02$. The results for the toast data showed the following for baseline-intervention; $z = 4.04, p < .001$, intervention-follow up; $z = 4.32, p < .001$, and baseline-follow up; $z = .91, p = .18$.

Table 1 shows the average number of errors made in each category and overall during each stage of experimentation within the tea data. Table 2 shows the average number of errors made in each category and overall during each stage of experimentation within the toast data.

Table 1: Tea data - Average number of errors for each stage of experimentation.

	Omission	Sequence	Semantic	Perseveration	Addition	Quality	Total
Baseline	4.2	3.2	1.2	3	1.1	0.8	13.5
Intervention	0.25	0	0.63	0.75	0.75	0.5	2.88
Follow up	0	0	0.1	0.2	0.1	0.1	0.5
Delayed follow up	0.77	1	0	1.77	0.88	0.33	4.77

Table 2: Toast data - Average number of errors for each stage of experimentation.

	Omission	Sequence	Semantic	Perseverative	Addition	Quality	Total
Baseline	4.41	1.64	0	1.88	0.88	1.82	10.64
Intervention	0.38	0.12	0	1	0.75	1	3.25
Follow up	0.3	0	0	0.4	0.1	0.2	1
Delayed follow up	4.75	0.5	0	1.38	0.38	0.13	7.13

Figure 1 plots the changes in the number of errors across sessions for the tea data, Figure 2 shows this for the toast data. The data shows all four stages of experimentation from baseline to when the intervention was implemented and the lasting effects of that intervention once it was removed. It also shows results after a delay of two months showing that some but not all of the effects of the intervention are apparent as errors did not reach baseline levels but were not as low as immediately after the interventions.

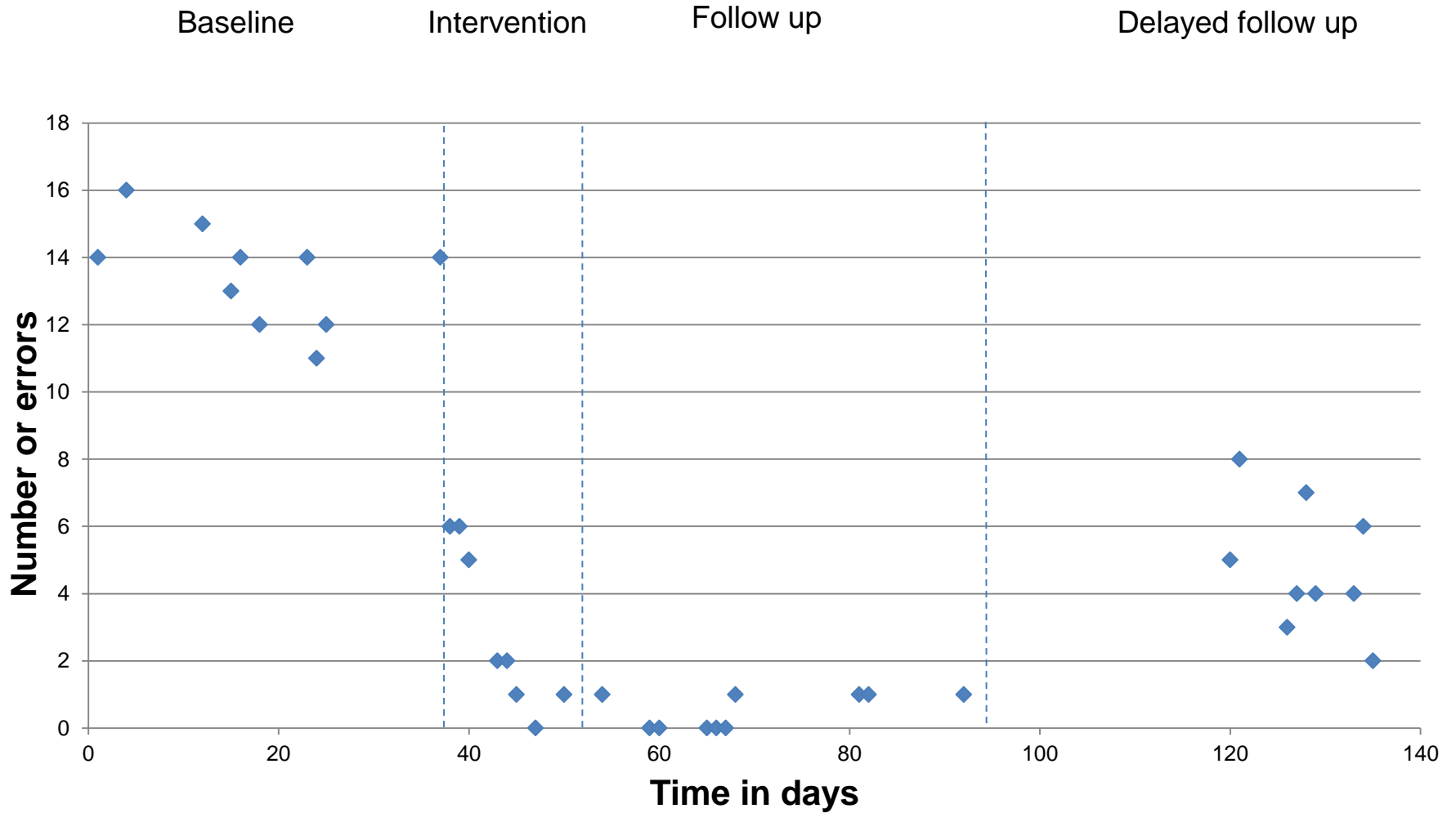


Figure 1: Scatter graph showing the number of errors made during the tea making task over time. Each point on graph corresponds to an observation.

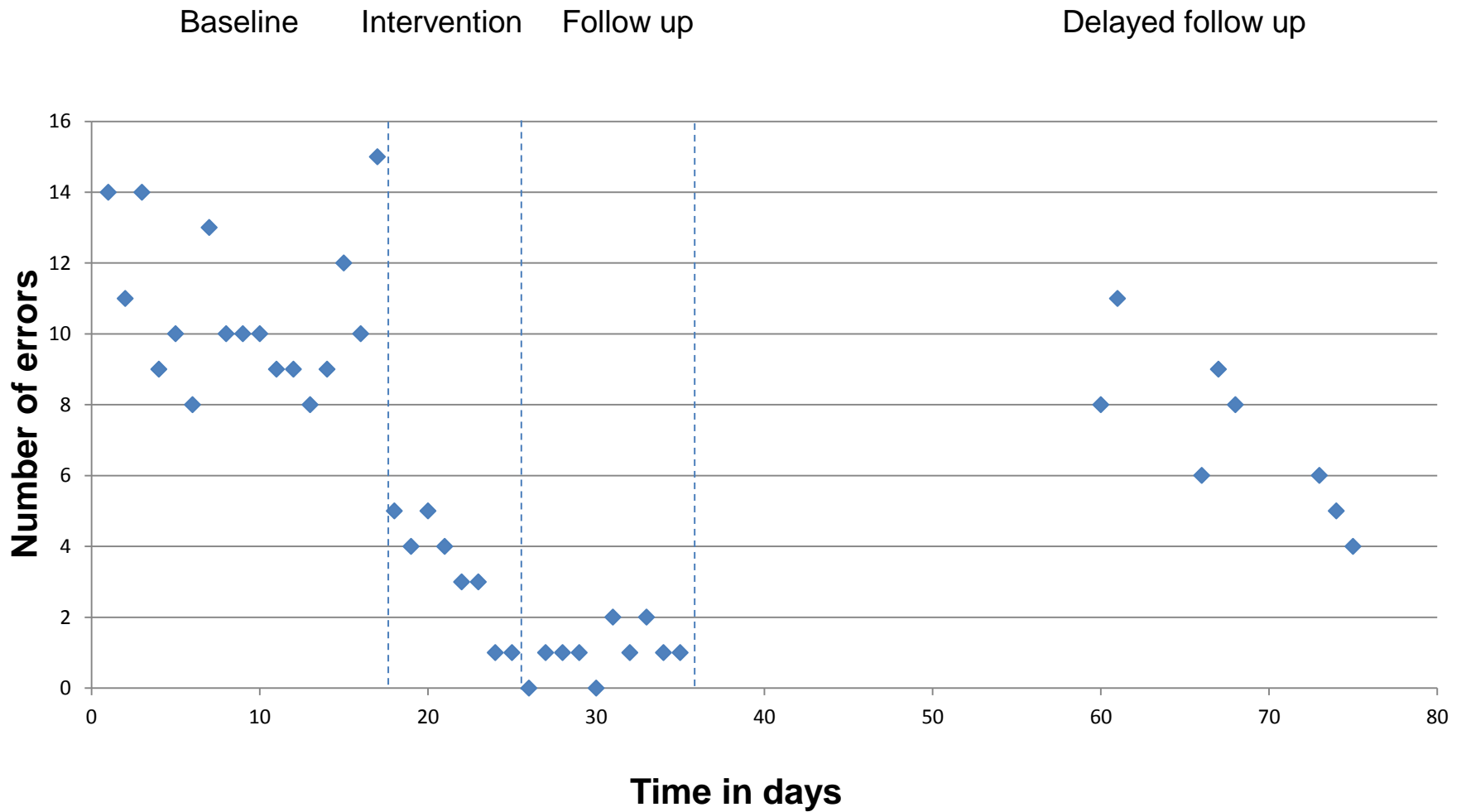


Figure 2: Scatter graph showing the number of errors made during the toast making task over time. Each point on graph corresponds to an observation.

Discussion

This study has examined whether two everyday routine sequential actions can be rehabilitated in a patient with a severe case of action disorganisation syndrome. This was achieved with the use of an errorless learning technique.

Results show significant differences in the number of errors made between the separate stages of experimentation. Correlation analysis was used to rule out the possibility that any changes were due to time and not due to the intervention: errorless learning. There was no decline in errors in the baseline stages of experimentation, which is important to show as it suggests that errors would not have declined naturally overtime. Errors declined rapidly during the intervention stages of both tasks with the introduction of the errorless learning technique. This validates its effectiveness in rehabilitating the ability to carry out two everyday tasks in a patient with severe ADS.

There was a significant negative correlation between the number of errors and time in the delayed follow up of the tea data. This is likely to be due to some practice effect that was not otherwise present in the baseline stage. No correlation was found in the delayed follow up stage of the tea data. It is likely that if errorless learning was introduced again here then a negative correlation would become apparent as in the intervention stage. Errors would be likely to decrease rapidly. This would be an interesting to investigate in future research.

The two graphs presented show the effects of the intervention clearly, with a high proportion of errors in the baseline, a decline in errors during the intervention and a relatively stable low score in the follow up. After a delay of approximately two months, the numbers of errors had increased but had not reached baseline levels. This somewhat refutes the hypothesis that the intervention would not have long-term effects, as errors increased less than originally suspected. However, errors did rise significantly, therefore in order to keep errors as low as during the immediate follow up stage, and to provide maximum benefit for rehabilitation, more regular usage of errorless learning is advised. The pattern was relatively similar for both tasks which further validates the effectiveness of errorless learning as an intervention.

This is consistent with findings of the meta-analysis conducted by Kessels and Haan (2003) and also the six experiments by Wilson, Baddeley, Evans and Shiel, (1994) who all studied the effects of errorless learning on rehabilitation of memory impaired participants. All found errorless learning to be an effective technique for tasks such as learning a list of words, naming objects and people and learning new items of general knowledge. This study has extended the research on errorless learning to another area of rehabilitation: action disorganisation syndrome. The technique has been successful in rehabilitating the ability to make both a cup of tea, and toast with butter and jam, in a patient with severe impairments in both language and memory.

Verbalisation techniques such as those used by Bickerton et al. (2006), found only small effects on rehabilitation and a lesser improvement for those with a greater severity of impairments (Donkervoort, et al., 2001). Other efforts included using written instructions and physically copying the experimenter's actions; however these were also found to be unsuccessful (Forde & Humphreys, 2002). It may be because these techniques require more concentration and thinking than is needed for the errorless learning technique used in this study, which is an implicit way of learning.

The techniques used by other studies mentioned may rely on the functions of the frontal lobes more so than errorless learning does. This could be one of the reasons that they would not work for case DL, as he has extensive damage to the frontal lobes. To take an example; impairment in energisation, which is a category of functioning within the frontal lobes, would affect the ability to initiate and sustain a response (Stuss, 2011). In Bickerton et al.'s (2006) study, success in the tea making task relied on the patient, FK, being able to initiate the verbal script. FK often forgot to do so which affected his rehabilitation potential within the sessions, and also across sessions. This could be due to reduced functioning in energisation, as FK presents with ADS which is associated with damage to the frontal lobes. It would be interesting to see if errorless learning could be implemented and achieve success with patients such as FK who have previously been very difficult to rehabilitate.

This study's use of errorless learning may have been successful because it appeals to a more procedural way of learning things. DL was physically directed to the correct sequence of the task throughout. For example, if DL had reached for the water before the teabag container, the experimenter would physically stop him from doing so and direct his hand to the correct object. This was accompanied by a verbal prompt. Procedural learning activates different parts of the brain than declarative memory uses (Ullman, 2004). Therefore, it may be that DL has spared capacities in the former and not the latter.

Qualitative Analysis

Looking more closely at the proportions of the types of errors made provides more insight to the impairments ADS patients suffer with. With further research it may be possible to specifically identify problem areas for the focus of rehabilitation. It highlights issues such as perseveration which is apparent not only within the experimental setting, but outside also with other behaviours and speech patterns.

When taking a closer look at the types of errors made during both of the tasks one can see that there were zero semantic errors made during the toast task across all stages of experimentation. This was the only category of errors to achieve no errors throughout all observations. This is likely to be due to the fact that distractions in the form of possible semantic intrusions were minimal. In the tea data, semantic errors such as misusing the spoon for drinking tea were of a relatively high occurrence. Here DL affords the use of the object to some other context, for example eating cereal. Here the error takes the form of an action performed in a different context, displaying an intrusion of incorrect semantic knowledge that could not be overcome (Reason, 1979). DL was prompted to drink in the conventional manner yet continued to use the spoon unless it was removed from sight/reach. When the spoon was removed DL always drank the tea normally. Other semantic errors that were made include retrieving a teabag from the container with a spoon and mopping up spilt tea with a used teabag.

In the toast task there are perhaps less chances to confuse uses for items. It is highly likely that if we introduced other items that were not relevant to the task, semantic errors would increase. This would be an interesting factor to introduce in future research. This has implications for the amount of independence that is achievable in patients with severe cases of ADS. Whereas the two activities used have been rehabilitated successfully, the environmental context is rigid with regards

to distractions. In another setting where distractions are present, it is likely that DL's performance would be poor.

Some types of errors were more frequent than others which may be for reasons such as the presence of environmental cues. For example, adding milk changes the colour of the tea and therefore acts as an external memory aid for the completion of that subtask, meaning that the likelihood of repeating that action is lower than would be for adding sugar, for example. Adding sugar provides no visual cue and therefore, if the participant has memory impairments, he or she has no sure way of knowing whether or not they have completed that subtask. DL would add up to 9 spoonful's of sugar on occasion. Whitehead and Lin (1995) give the example of an environmental cue in the 4 step process of; opening a box, putting a gift in, closing the box and sealing it. If only driven by visual percepts, the person cannot complete this task because once the box is closed the person does not know if the gift is in the box and therefore cannot decide whether to open or seal the box. Case DL often perseverated on adding sugar and the lack of external cue could be a contributing factor as to why this happened.

Another reason for adding a vast amount of sugar is the fact that perseveration is a common symptom of ADS/frontal lobe injury. This has been found in many studies including Bickerton et al.'s (2006) and Botvinick and Plaut's (2004) computer simulation study. Whereas the lack of visual cue for adding sugar may have been an important contributing factor to the error, other instances of perseveration provided clear visual cues and therefore lack of visual cue cannot be the reason for the error here. On one occasion DL added teabags to the mug to the point that the mug was almost full, after which he then attempted to add water. Here an environmental cue was clearly not sufficient to inhibit perseveration on the sub-task. Another common perseveration error DL often made was with stirring the tea. DL would spend long periods of time stirring the tea both when it was appropriate (for example after adding milk/sugar) and inappropriate (such as before adding milk or with only boiling water in the cup). On occasions where it was not necessary to stir the tea, the action was coded under an addition error.

DL also perseverated for long periods of time when spreading butter/jam on toast. He would need to be heavily prompted on occasions in order to move on to either the second piece of toast or even to another area of the same piece of toast. DL would spend much time spreading in one small area, using only the tip of the knife at times. It was not uncommon for DL to spend more than 10 minutes spreading butter/jam. Other perseveration errors during the toast task included continually taking bread out of the packet, although this was less frequently noted.

DL was often worse at spreading the butter than the jam. It is unclear why this was but it may be that the jam provides a stronger visual cue for where he has/hasn't already spread. It would be interesting to investigate whether exchanging the product used on the toast would affect DL's performance; for example using marmalade or spreadable pastes. If so then this would show some generalisation for the use of errorless learning although only a small amount as this would only marginally change the task. It is unlikely that the errorless learning will have shown generalisation to other unrelated tasks as has been found in other studies focusing on rehabilitating everyday action in ADS (Bickerton et al., 2006; Goldenberg et al., 2001; Goldenberg & Hagmann, 1998).

Perseveration was an issue for DL both in and out of the experimental environment; it was present in other behaviours and also his speech patterns. For example, on one occasion DL was verbally prompted with “What comes next?” during the task. DL then proceeded to say “What come next” perseveratively throughout the duration of the task. There was no inclination that he did not know what to do next as he continued with the task. Dissociation between speech and action is typical of frontal lobe damage although it is rare to the extreme that DL presents with (Nauta, 1971). Speech perseveration occurred on many occasions during the tasks as he would often say things such as “I can’t”, “How?”, “What do I do?” or “I’m not hardworking”. He perseverated on these phrases despite continuing with the task and often without directing his speech towards the experimenter.

DL was also very stuck on the idea of having a cigarette. He would often perseverate on the word “cigarette” both in and out of experimental sessions even when he had only just been given a cigarette. Sessions with DL were often delayed due to the request for a cigarette. Immediately after, DL would then request another. This could be due to perseveration of speech but also the fact that his memory was extremely poor as he would often deny having just been for a cigarette.

Case DL made several addition errors, described as “independent actions” in Botvinick and Plaut’s (2004) paper, which are actions not necessary for completion of the goal. Examples of DL’s addition errors include putting a teabag in the milk carton, putting the spoon in the teabag container and scooping up breadcrumbs/sugar/general mess from the table and proceeding to eat them/put them in the tea. DL was prompted to stop this on these occasions and encouraged to continue with the task. DL would also lift items such as the milk carton unnecessarily and place them back down or on top of another item such as the plate used for the used teabag. During the toast task DL produced random actions such as lifting the plate and placing it back down on top of the tub of butter or bread packet. DL also made addition errors such as putting the used teabag back in the tea, repeatedly boiling the kettle, unnecessarily removing the lid of the kettle, stirring the tea with nothing in it and using the mug to bang on the table. Addition errors during the toast task included making a sandwich with the two pieces of toast and dipping it in tea, fiddling with toaster settings, and scooping up breadcrumbs and putting them either in the toaster or in the bread packet. Addition errors have also been reported in other studies such as Schwartz et al. (1991) in the context of making coffee. These actions are produced randomly directly due to the ADS.

Towards the end of the toast data collection, during the delayed follow up stage, case DL was given omission errors for not using jam. This may not have been that he was forgetting to use the jam but instead that he simply did not wish to use it. When prompted to add jam he on occasion would reply with “no” in a perseverative manner. It was explained to him that he needed to add jam in order to complete the task however he still did not do so. Omission errors were awarded on all occasions where this occurred, which may not have been entirely appropriate. Not awarding these errors would reduce the number of errors made in the delayed follow up stage and would present the effectiveness of errorless learning as more successful than it stands presently.

Other omission errors made by DL include forgetting to use water, a teabag, milk and also forgetting to remove the tea bag and to replace lids on items. During the

toast task DL occasionally forgot to toast the bread and to spread butter/jam. This is consistent with what has been found in other studies of patients with ADS (Buxbaum et al., 1998; Humphreys & Forde, 1998; Schwartz et al. 1998).

In the baseline stages of experimentation, omission errors were the most common type of errors made, which is also what other studies of ADS have found including a computer simulation study for making a cup of tea (Botvinick & Plaut, 2004; Schwartz et al., 1998). However, after the implementation of errorless learning, this was no longer true suggesting that errorless learning is more successful in reducing the number of omission errors than other types of errors which are perhaps more difficult to rehabilitate.

Sequence errors made during the tea making task include using water before the teabag and using milk prior to anything else. On one occasion when DL used milk first, he almost filled the mug of milk and was therefore awarded a quality error along with the sequencing error. During the toast task DL on occasion used butter before toasting the bread, and often went to use the jam before the butter, perhaps because the jam provided a stronger visual cue (although this is not conclusive).

Quality errors coded included instances where DL used too little or too much water and/or milk, unevenly spreading butter/jam, taking out toast before it was ready and attempting to pull out toast with fingers instead of using the lever.

Looking at the types of errors made poses questions and a focus for future research in that it may be possible to concentrate on reducing certain types of errors that are more difficult to rehabilitate.

A major point to note is that, in this study, items were presented in the correct order for DL. For example, from left to right on the table he sat at stood the packet of bread, followed by the toaster, butter and finally jam. The plate and the knife were set directly in front of him. If items would not have been presented in this way it is highly likely that the number of errors made would increase dramatically. This means that whilst the two everyday routine sequential actions are rehabilitated, it may be that in a more naturalistic setting, where things aren't necessarily set out in this way, DL's independence in the task could be significantly decreased. Being outside of the rigid experimental setup would add many distractors not otherwise present in this study. This phenomenon is presented by Botvinick and Plaut's (2004) computer simulation study which found that as increasing amounts of noise (synonymous to distractions) were added, the number of errors made was also increased. They also noted that with lower amounts of noise, errors were made at a between-task level or "branch points" which corresponds to errors made by non-impaired individuals. Higher levels of noise caused errors at a within-task level which is typical of individuals with ADS and what was observed in DL. A focus for future rehabilitation in case DL could be slowly adding distractions and/or new environments and using errorless learning in an attempt to keep the errors low.

Implications for future research

Considering the severe and complicated impairments in DL, it is quite staggering to have achieved such clear and successful results. As discussed earlier, this may be because the strategy uses procedural learning, rather than explicit/declarative learning as in papers such as Bickerton et al.'s (2006) that use verbalisation techniques. The success of this study has implications for future research in

rehabilitation. The use of errorless learning has been successful in rehabilitating two routine sequential actions - making tea and toast with butter and jam - in a patient with severe impairments in frontal lobe functioning. Therefore, it may be that the use of errorless learning could work for other patients who present with similarly severe impairments. It would also be interesting to see if errorless learning can aid the rehabilitation of other abilities such as activities of daily living (ADL). These include washing, dressing, grooming, self-feeding and functional transfers (getting out of bed/wheelchair etc.). These activities could take the same experimental set up as this study. A final interesting and beneficial focus for future research and rehabilitation in this area would be to slowly introduce distractors to tasks in attempt to achieve rehabilitated abilities in a more naturalistic environment.

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