A Pilot Investigation of the Potential for Incorporating Lifelog Technology into Executive Function Rehabilitation for Enhanced Transfer of Self-regulation Skills to Everyday Life

Gustavo Cuberos-Urbano[1], Alfonso Caracuel[2,3]*, Carlos Valls-Serrano[1], Leticia García-Mochón[4], Fergus Gracey[5,6], Antonio Verdejo-García[1,7,8]

[1]Department of Clinical Psychology, School of Psychology, University of Granada, Granada, Spain.

[2]Mind, Brain and Behavior Research Center, University of Granada, Granada, Spain.

[3]Department of Developmental Psychology, School of Education, University of Granada, Granada, Spain.

[4]Escuela Andaluza de Salud Pública, Junta de Andalucía, Granada, Spain.

[5]Oliver Zangwill Centre for Neuropsychological Rehabilitation, Cambridgeshire Community Services NHS Trust, The Princess of Wales Hospital, Ely, Cambridgeshire, UK

[6]Department of Clinical Psychology, Norwich Medical School, University of East Anglia, Norwich Research Park, Norwich, UK.

[7]Institute of Neurosciences F. Olóriz, School of Medicine, University of Granada, Granada, Spain.

[8]School of Psychological Sciences & Monash Institute of Cognitive and Clinical Neuroscience, Monash University, Melbourne, Australia

*Author for correspondence:

Alfonso Caracuel

Facultad de Educación, Universidad de Granada

Campus de Cartuja S/N, 18071

Granada (Spain)

acaracuel@ugr.es

Abstract

Objective: To identify potential target and size of effect of GMT enhanced with life-logging technology compared with standard GMT on a range of possible primary outcomes reflecting cognitive and ecological aspects of executive functioning and quality of life.

Methods: Sixteen patients with acquired brain injury involving executive dysfunction were randomly allocated to one of the two interventions: seven weeks of GMT (n=8), or seven weeks of GMT+Lifelog (n=8). Outcome measures included a battery of executive function tests, the Dysexecutive Questionnaire (DEX) and the Quality of Life after Brain Injury scale (QOLIBRI) measured pre and post interventions. Within-group changes were assessed with related-samples t-tests and estimation of effect sizes.

Results: GMT+Lifelog was associated with significant changes, of medium to large effect size, in response inhibition (Stroop), multitasking (Strategy Application and Multiple Errand tests), DEX Intentionality and Positive Affect subscales and QOLIBRI Daily Life and Autonomy, subscales. GMT alone was associated with significant changes of overall quality of life.

Conclusion: GMT+Lifelog holds promise to optimize the impact of GMT on executive dysfunction and quality of life.

Key words: Executive function; Goal Management Training; Lifelog Technology; SenseCam; ActiHeart; Acquired Brain Injury

INTRODUCTION

Forty percent of patients with acquired brain injury have significant deficits in executive functions (Nys et al., 2007). These deficits are generally broad and persistent, including problems with working memory, reasoning, response inhibition, flexibility and planning/problem solving skills (Barker-Collo & Feigin, 2006; Dikmen et al., 2009). Executive function rehabilitation is focused on planning/problem solving skills, but current interventions are less efficacious in improving response inhibition, error awareness and self-regulation (Hart & Evans, 2006; McDonald, Flashman, & Saykin, 2002). These executive deficits are associated with real-life problems in achieving desired goals (Rabinowitz & Levin, 2014), and with poorer performance in activities of daily living and reduced quality of life (Reid-Arndt, Nehl, & Hinkebein, 2007). There are several interventions to address executive dysfunction in patients with acquired brain injury (Cicerone, Levin, Malec, Stuss, & Whyte, 2006) but most of these interventions are modestly efficacious in improving executive deficits associated with self-regulation and real-life decision-making (Kennedy et al., 2008).

Goal Management Training (GMT™) is a group intervention for executive dysfunction related to brain injury. GMT has a strong theoretical foundation, based on Duncan's goal neglect theory of executive functions (Duncan, 1986). GMT uses cognitive exercises and psychoeducation to strengthen mindfulness and attentional control skills to enable better goal activation and goal-directed behavior (Levine et al., 2011; Levine et al., 2000; Levine, Manly, & Robertson, 2005). The training is delivered in seven to nine modules of two hours each (one module per week) in small groups (4 to 8 participants) and administered by healthcare professionals such as occupational therapists or neuropsychologists. Cognitive exercises are focused on sustained attention, working memory and cognitive control. Psychoeducation is focused on explaining the antecedents and the consequences of attentional 'slips' and related goal mistakes (e. g., clearing the table after breakfast, put the butter in the fridge and drop the car keys without realizing it, and being late to work). These strategies are complemented by promotion and supervision of real-life goal projects among participants (e. g., charge of organizing a weekend camping), which enable them to transfer the trained cognitive exercises into daily life problems. These projects are also an opportunity for participants to make mistakes, and for GMT to use these examples to provide corrective feedback and consolidate the trained strategies. A detailed description of objectives and exercises of sessions can be found elsewhere (Levine et al., 2011; Tornås et al., 2016)

GMT and related goal-related interventions are efficacious to improve performance in cognitive tasks analogous to the ones used during training (sustained attention, planning) and participation in daily life activities (Levine et al., 2011; Novakovic-Agopian et al., 2011). However, there is less consistent evidence of GMT's efficacy in improving other executive functions (e.g., working memory, response inhibition, error detection) (Krasny-Pacini, Chevignard, & Evans, 2014). In fact, research indicates that GMT has more positive effects on executive functions when meaningfully combined with generalisation strategies such as external cueing (Tornås et al., 2016) when applied with greater frequency and intensity (Krasny-Pacini, Chevignard, & Evans, 2014).

Approaches such as GMT rely on discussion of recent personal experiences as well as discussion of hypothetical situations included in the training material to facilitate learning and application between sessions. Hypothetical examples can be easier for some patients to discuss at the beginning of rehabilitation. However alone these may not be sufficiently strong or concrete enough to enhance links between situational cues and desired behaviours/goals between sessions in day-to-day life. A recent review and clinical trial (Schmidt, Lannin, Fleming, & Ownsworth, 2011; Schmidt, Fleming, Ownsworth, & Lannin, 2013) indicates the usefulness of video and verbal feedback for improving self-awareness and extension of this to day-to-day life, specifically improving error self-regulation during a task (Schmidt et al., 2013). Discussion of personal experiences and application in daily life might also facilitate generalisation and application of training. However, recall of sufficiently detailed personal examples in the group, and prospective recall and implementation of strategies is required for this to be helpful. Hewitt, Evans and Dritschell (2006) found that when people with ABI were prompted to use a strategy to enhance autobiographical recall prior to completing an executive practical solution generation task, their solution and plan development was significantly improved. Therefore, support for recall of personal events and reviewing of video of performance on tasks may enhance utility of the training methods and transfer from session to day-to-day life.

Lifelog technologies (i.e., technology to constantly record and later review or share human experiences) are therefore of potential benefit for enhancing autobiographical recall within rehabilitation and error self-regulation or self-monitoring in day-to-day tasks. Application of lifelog technology could increase the power of standard executive rehabilitation by strengthening links between the brain injured person’s everyday life experiences and their clinic rehabilitation appointments. SenseCam (Berry et al., 2007; Hodges, Berry, & Wood, 2011) is a portable lifelog camera that is worn around the neck. Images are captured when motion and light sensors are triggered. When reviewed in sequence the images provide a ‘stop frame’ type movie from the wearer’s perspective. Research suggests that reviewing such movies enhances autobiographical memory retrieval (Berry et al., 2007), and retrieval of thoughts and feelings related to the event (Brindley, Bateman, & Gracey, 2011) in cases of memory impairment. Although used for tackling autobiographical memory deficits it is readily applicable for detection of executive dysfunction related slips and mistakes during everyday activities and enhancing associations between trigger situations, cues for alternative behaviours and new behavioural responses. This is therefore a viable device for enhancing recall and self-awareness of everyday executive problems. ActiHeart is also a portable device indexing heart rate, inter-beat interval and actimetry across long time spans (Takken et al., 2010). Importantly, the visual outputs from SenseCam and ActiHeart recordings can be viewed together via the respective available software packages, such that visual information from the external world and physiological input from the internal milieu can be jointly analyzed in relation to real-life personal and social scenarios. In practice this provides a means for the rehabilitation practitioner to identify trigger situations where there has been an affective response without relying on patient self-report or autobiographical memory retrieval ability. This also provides a means of engaging the patient in identifying specific internal (physiological) and external (environmental) details of the situation to facilitate problem solving, self-awareness, identification and practice of more adaptive alternative behaviours.

The aim of this study was to carry out a pilot investigation to identify potential target and size of effect of Goal Management Training (GMT) enhanced with life-logging technology compared with standard GMT on a range of possible primary outcomes reflecting cognitive and ecological aspects of executive functioning and quality of life. We anticipated that the combined GMT + lifelog intervention would enhance the self-monitoring aspects of GMT, as well as the generalization of GMT trainings to daily life activities. Since SenseCam provides real-life examples of attentional slips and goal errors, and participants can review these mistakes with the guidance of the therapists, GMT + SenseCam can improve error detection and self-regulation, as indicated with multitasking tests. Therefore, we hypothesized that larger effect sizes will be yielded for GMT+lifelog in (i) executive tests related to self-monitoring and (ii) ecologically valid ef measures and (iii) QoL.

METHODS

Design

The study employed a randomized parallel-groups pilot trial design comparing performance pre and post intervention (either seven weeks of GMT+Lifelog or GMT alone) on a range of measures to determine effect sizes. Following consent and baseline assessments, participants were randomly allocated into one of the two interventions: GMT+Lifelog (n=8) and GMT only (n=8). Randomisation was carried out according to the statistical principles for clinical trials (Lewis, 1999) by an independent statistician not involved in the day-to-day conduct of the trial. Following eligibility assessments, participants were assigned randomly to the treatment condition using a ratio of 1:1. Treatment allocation concealment was achieved by using a password protected computer program, implemented by an independent member of the Hospital administration team who informed the project manager of the outcome via email. The project manager informed the treating team and the participants about the randomisation outcome. Outcomes were measured within two weeks after interventions ended.

Participants

Sixteen individuals (2 women) with acquired brain injury were recruited from the Rehabilitation Unit at the "Hospital Virgen de las Nieves" in Granada, Spain, where they were undergoing outpatient treatment consisting of physical rehabilitation and psychoeducation. The eligibility criteria were defined as follows: aged >18; being able to understand, read and speak Spanish; symptoms of executive dysfunction indicated via clinical reports of the treating team; a minimum of 6 months post-injury. Problems related to executive functions were assessed via clinical interviews with the patients and collateral informants (spouses or relatives). All selected participants had significant real-life problems in planning and sequencing, impulsivity and disinhibition, poor emotional self-regulation and self-awareness of deficits, as reported by the informants. In addition, collateral informants completed the informant-form of the Frontal Systems

Behavior Scale –FrSBe (Grace & Malloy, 2001). The results of the FrsBe confirmed that all participants fell at least 1.5 standard deviations below the mean in the global scale. Exclusion criteria consisted of: severe cognitive (i.e. non-executive) deficits that could interfere with the patient's ability to engage in the training, indicated with a comprehensive neuropsychological assessment, and DSM-IV Axis I disorders indicated by informant reports and medical records. Etiology of injuries was mixed: five participants have had stroke and 11 participants traumatic brain injury, all with evidence of frontal lobe injury on MRI or CT Scan.

Participants were recruited in two different waves between starting date – end date. They were recruited through an opportunity sampling approach, which is adequate for pilot studies (Marcus & Soso, 1989): the first eight patients evaluated in the Unit after a certain time and who met the inclusion criteria were included and randomized into the two groups to start each wave.

The Ethics Committee for Human Research of the "Hospital Virgen de las Nieves" approved the study. All participants provided written informed consent for participation.

Intervention Procedures

GMT only: GMT^{TM} was delivered in groups of 4 participants following the trainer's manual and presentation and homework materials developed by Baycrest (Levine et al., 2005). The training comprised 7 modules, implemented in 14 one-hour sessions: two per week distributed across 7 weeks. The contents of GMT sessions have been detailed in Levine and cols. (2011). Patients' own experiences were frequently used to facilitate learning transfer from sessions to daily activities.

GMT+Lifelog: GMT^{TM} was combined with the SenseCam and ActiHeart devices. These lifelog devices were used to sample participants' everyday life experiences in-between GMT^{TM} sessions. Lifelog recordings (i.e. SenseCam and ActiHeart outputs) were uploaded to computer before each session, and scanned to identify relevant examples of e.g. goal errors to provide personalized feedback during the sessions. Identification of relevant examples was achieved via focusing on instances in which participants experienced peak heart rates in ActiHeart recordings, and tracking the SenseCam images corresponding to these peaks. Situations in which peak heart rates overlapped with executive dysfunction manifestations, based on the judgment of the treating team, were selected to provide video-feedback during the sessions. Therefore, lifelog recordings were used for three main purposes: (i) to identify everyday situations in which goal-neglect behaviors arise; (ii) to provide specific feedback about these real-life problems via standard GMT strategies; and (iii) to raise awareness and boost ongoing monitoring of slips in subsequent everyday situations (between sessions).

Both groups ran in parallel during the same 7 weeks, and the same therapists were involved in both interventions (co-authors GCU and AC). Pre- and post-intervention assessment of outcome were conducted by an independent researcher (CVS), who was blind to intervention allocation.

Outcome measures

Neuropsychological measures were administered at baseline (i.e. within two weeks prior to interventions onset), and at post-intervention (i.e. within two weeks following completion of interventions).

Executive function tests included the Raven's Colored Progressive Matrices (Raven, 2004); the Letter Number Sequencing subtest of the Wechsler Adult Intelligence Scale III (Wechsler, 1997); and the Stroop Color and Word Test (Golden & Freshwater, 2002).

Ecologically valid tests included the Zoo Map test – version 1 of the Behavioural Assessment of the Dysexecutive Syndrome Battery – BADS) (Wilson, Alderman, Burgess, Emslie, & Evans, 1996); the Revised-Strategy Application Test (R-SAT) (Levine, Dawson, Boutet, Schwartz, & Stuss, 2000a); and the Multiple Errands Test – Hospital version (MET) (Knight, Alderman, & Burgess, 2002), which had been previously adapted to our context (Cuberos-Urbano et al., 2013)

Questionnaire measures included the Dysexecutive Questionnaire –DEX, Informants version rated by the patient's relative that spent more time with his/she (Wilson et al., 1996), and the Quality of Life after Brain Injury –QOLIBRI (von Steinbüchel, et al., 2010a). Both questionnaires have good reliability and validity (Bennett, Ong, & Ponsford, 2005; von Steinbüchel, et al., 2010b).

Statistical Analysis

Kolgomorov-Smirnov tests supported the normality of the distributions of the main dependent measures. Baseline differences between groups were tested with independent-sample t-tests. The relative impact of both interventions was calculated using effect sizes estimates (Zakzanis, 2001), which are not influenced by sample size, and may be particularly sensitive to the effect of both neuropsychological interventions in this clinical sample. The effect size was calculated using Cohen's *d* corrected for dependence between means using equation number 8 of Morris & DeShon (2002) for cases of repeated measures. Results from the effect sizes estimations were interpreted following Cohen´s recommendations (1988): they were considered medium if above 0.5, and large if above 0.8.

RESULTS

Comparison of background characteristics

Participants were aged between 24 and 50 years (mean=35.24; SD= 10.75), and their number of years of education ranged between 8 and 18 years (mean= 10.41; SD= 2.55). Average time since injury was 58.63 months (SD= 48.19; range 6-153). These characteristics did not significantly differ between the two intervention groups (p= .849) (see Table 1). The distribution of lesion etiologies did not differ between the groups: GMT+Lifelog group (TBE=6 and stroke=2); GMT group (TBI=5 and stroke=3), Pearson's *Chi-square* =.291, *p*=.59.

Insert Table 1 here

Neuropsychological changes associated with the interventions

Results are displayed in Table 2, including descriptive data and effect sizes estimates for outcome measures of cognition, everyday life related executive dysfunction, and quality of life.

Both interventions produced improvements in most variables. Participants enrolled in GMT+Lifelog achieved large effect size improvements in two cognition measures (Zoo map and R-SAT proportion of brief items) and the QOLIBRI Daily life and autonomy score. This group also achieved a large reduction in MET task failures and DEX scores of Intentionality, Executive memory and Positive affect.

Participants enrolled in GMT alone showed several medium effect size improvements in cognition (Letter-Numbers Sequencing and R-SAT proportion of brief items), MET (Task failures and Rule breaks), and the QOLIBRI (Cognition, Self and Daily life and autonomy).

In terms of the difference between groups in the effect size of improvements, the GMT+Lifelog group got positive differences in all but four measures. The greater differences were in three cognitive measures (Zoo map, Stroop Interference and R-SAT proportion of brief items) and three DEX subscales (Intentionality, Executive memory and Positive affect.), ranging from .71 to .94. Differences in favor of GMT-alone group were in Raven Matrices, MET total rule breaks and Cognition and Self QOLIBRI subscales, range of .1-.46.

Insert Table 2 over here

DISCUSSION

We aimed to provide potential target and size of effect of GMT enhanced with life-logging technology compared with standard GMT on a range of primary outcomes reflecting cognitive and ecological aspects of executive functioning and quality of life. Results showed that the combined "GMT + lifelog" intervention is associated with improvements of large effect size in executive tests tapping into self-monitoring (Zoo Map, R-SAT, MET task failures and errors), participation indices of executive memory, intentionality and positive affectivity (DEX) and quality of life index of daily life and autonomy. GMT alone only achieved changes of mild to moderate effect sizes in these domains.

Quantitatively, the comparison between the effect sizes achieved by the two interventions indicate that the lifelog technology is topping up GMT in the predicted way: participants enrolled in the combined intervention display more meaningful improvement of planning, self-monitoring and error detection as indicated by improved performance in the Zoo Map, R-SAT, and MET tests. We hypothesized that SenseCam would make participants more mindful about the need to plan their behaviours before acting, and also more aware of their own mistakes. These aspects clearly complement the GMT strategies of "Stop-State" and "Check". Therefore, SenseCam seems to contribute to boost the effects of GMT on executive functions, one of the current limitations of this training (Krasny-Pacini et al., 2014). These effects seem to transfer to related indices of participation: participants enrolled in the combined intervention display meaningful improvement of executive memory and intentionality. These domains have shown to be significantly associated with executive measures of rule shifting and multitasking, similar to R-SAT and MET (Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Zelazo et al., 2003). Therefore, SenseCam also seems to contribute to link executive gains with relevant aspects of daily life.

Qualitatively, the reviewing of the SenseCam movie alongside heart rate recordings of participant's own real-life situations in a group setting appeared to engage participants more fully in problem solving. Group participants also appeared to develop stronger social ties through the group than were evident in the GMT alone group. For instance, there were more examples of spontaneous peer support observed within the GMT plus lifelog group. Considering the identified quantitative changes alongside qualitative reports, we propose that the added benefit for transfer of skills to everyday life and well-being of including Lifelog devices within GMT may pertain to two domains: (i) Improved binding of strategies learned in the group to real-world situations through rehearsal of personal, real-world examples as indicated by improvements in cognitive self-monitoring and real-life autonomy. This might facilitate improved autobiographical recall in turn supporting problem solving (Hewitt et al., 2006) as well as feedback to improve error self-awareness (Schmidt et al., 2013) and discrepancy between perceived and actual daily challenges (ii) Engagement with personal, real-life experiences through reviewing movies might facilitate group cohesion, and provide greater opportunities for emotional and practical support and understanding from peers. Social group membership itself may be a factor in improved well-being following ABI (Haslam et al., 2008; 2010; 2014). The importance of social group processes is also emphasized in comprehensive day programme rehabilitation as a core component (Wilson, Gracey, Malley, Bateman, & Evans, 2009).

Therefore, the incorporation of lifelog devices may have allowed us to better identify particular real-life difficulties between sessions to specifically train participants during sessions and improve self-monitoring and implementation in subsequent everyday scenarios. These examples are consistent with contemporary and evidence-based approaches to neuropsychological rehabilitation that stress contextualized metacognitive skills training (Cicerone et al., 2011; Gracey & Ownsworth, 2012; Kennedy et al., 2008; Tate et al., 2014). However, these approaches require training 'in vivo'. The present study suggests that incorporation of lifelogging may provide 'cueing and mnemonic enhancement' of rehabilitation and reduce reliance on the difficult to organize on-task training in day-to-day life. Improvements in the intentionality of DEX might be related to this. As examples from patients' lifelog have been used for training, similar real life situations might activate the meta-strategy trained in GMT sessions.

Our results should be interpreted in the context of a pilot "proof of concept" study (Lancaster, 2015). We have shown that GMT can be successfully combined with lifelog technology, and that the combined intervention is associated with meaningful changes in the expected outcomes: cognitive skills related to self-monitoring, better use of executive functions in everyday life and quality of life. In addition, the study provides critical information to estimate the sample size required to detect a significant effect in a standard randomized clinical trial. Nonetheless, we are cognizant of the fact that this approach cannot draw conclusions about the comparative efficacy of these two intervention modalities, as the sample size precluded us from formally testing interaction effects in omnibus group*intervention mixed models. As this pilot study has given a strong indication of possible effect sizes and identified measures that may be sensitive to change resulting from this intervention, future RCT studies with larger sample size should resolve this issue. Nonetheless, given the effects of the intervention were specific to hypothesized measures relating to transfer to daily life, we are confident that pre-post results are reflective of active effects of the intervention.

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