Abstract.

BACKGROUND: Previous findings had shown that the addition of errorless learning to traditional Goal Management Training (GMT) resulted in superior results when training everyday tasks in persons with executive deficits after brain injury.

OBJECTIVE: To investigate the additional effects of an errorless GMT on cognitive function and quality of life after acquired brain injury.

METHODS: This is a supplementary analysis of findings from an RCT in which 67 patients with executive impairments after acquired brain injury were randomly allocated to an experimental errorless GMT (n = 33) or conventional GMT (n = 34) to train two individually chosen everyday tasks. Objective cognitive function using neuropsychological tests, subjective cognitive complaints and quality of life using questionnaires were assessed before and after training.

RESULTS: No significant interaction effects between these three types of outcome measures and the two forms of GMT were found. Irrespective of treatment, performance on two executive tests (Modified Six Elements Test; p = 0.006, Zoo Map test; p = 0.001) improved and daily executive function problems as reported by the participants (EFI; p = 0.001) and proxies (DEX; p = 0.01) diminished.

CONCLUSIONS: Besides the previously found superiority of errorless GMT when training everyday tasks, additional improvements in cognition and quality of life did not differ between the two treatments.

Keywords: Cognitive rehabilitation, cognitive function, executive function, quality of life, activities of daily living

1. Introduction

Goal Management Training (GMT; Robertson, 1996) is a cognitive rehabilitation intervention for brain-injured persons with executive impairments aimed at training complex everyday activities. These patients, who experience problems with goal-directed behavior, are taught to apply an algorithm through which everyday tasks are subdivided into multiple steps. The main aim is to teach patients to ‘stop and think’ after each completed task step in order to monitor performance and to maintain the end goal of the task actively in working memory (Levine et al., 2000). Previous studies have shown that GMT is effective, especially in combination with other rehabilitation interventions, such as problem solving.
therapy (Krasny-Pacini, Chevignard, & Evans, 2014). Another approach to the training of daily tasks is errorless learning. Here, the occurrence of errors is prevented during the learning of task steps (Baddeley, 1992). Although the effectiveness of errorless learning has been established in amnesic patients (e.g., in Alzheimer’s Dementia) it may also be beneficial for execively impaired patients. These patients have problems with error-monitoring and difficulties in adjusting behavior on the basis of feedback (Clare & Jones, 2008).

Our recently published RCT (Bertens, Kessels, Fiorenzato, Boelen, & Fasotti, 2015) was the first in which errorless learning and GMT were combined. The study showed that this combination resulted in a larger improvement of performance in self-chosen everyday tasks compared to GMT only. In the present study we investigate additional parameters. The aim is to examine whether errorless GMT also contributes to improvements of cognitive function, as measured with neuropsychological tests, and subjective cognitive function along with quality of life assessed with questionnaires. Although our trial was aimed at improving self-chosen everyday tasks, the results may generalize to ecologically valid executive function tests. Moreover, we hypothesize that improved everyday function may contribute to a reduction of cognitive complaints and a better quality of life.

2. Methods

The treatment protocol has been published elsewhere (Bertens, Fasotti, Boelen, & Kessels, 2013). In short, patients with executive deficits due to acquired brain injury of non-progressive nature were recruited from four rehabilitation centers between 2012 and 2014. Participants gave written informed consent before engaging in the study and all data were obtained in compliance with the Helsinki Declaration. The study is approved by the Medical Review Ethics Committee region Arnhem-Nijmegen (reference NL38019.091.11) and registered at the Netherlands Clinical Trials Registry (reference no. NTR3567).

2.1. Procedure and interventions

Both the experimental errorless and the conventional GMT comprised 8 one-hour individual sessions, administered twice a week by trained therapists. In the first two sessions, identical for both treatment arms, two treatment goals (i.e., self-chosen everyday tasks) were selected. After Session 2, baseline assessment took place in which the patient performed both tasks. This performance was videotaped and rated by assessors who were blind for treatment condition. The patients were randomly allocated to one of the treatment conditions using computerized block randomization. In errorless GMT, both the acquisition and application of the GMT strategy, including learning and performing the task steps, were taught using error reducing methods such as verbal and written instructions, cue cards and modeling. In contrast, during conventional GMT trial-and-error learning was allowed. In this condition the trainer did nothing to prevent errors, but only provided feedback in response to errors. Although patients were encouraged to apply the GMT and perform task steps, the trainer did not intervene to define or prompt task steps. After treatment the performance of both everyday tasks was again videotaped and rated.

2.2. Outcomes

Nine neuropsychological tests assessing executive and memory function as well as attention and concentration (see Bertens et al., 2013 and Table 1 for test details) were administered as part of the recruitment procedure. Everyday executive complaints and problems were assessed in both the patients and their proxies using the Dysexecutive Questionnaire (DEX). To measure self-reported cognitive and executive complaints patients also completed the Cognitive Failures Questionnaire (CFQ) and the Executive Function Index (EFI). Proxies completed the Executive Observation Scale (EOS) as an observational measure for executive function (see Bertens et al., 2013 and Table 2 for details). Quality of life was evaluated with the RAND-36 (see Bertens et al., 2013 and Table 3). All questionnaires and tests were also administered after treatment, using parallel versions if applicable.

2.3. Analyses

GLM repeated measures analyses were used to examine the effects of the interventions on neuropsychological test and questionnaire results. Alpha was set at 0.01 to correct for multiple testing. For the neuropsychological tests, regression-based Reliable Change Indices (RCI) were computed that take non-systematic measurement errors and systematic
Table 1
Mean (SD) for neuropsychological tests (objective cognitive functions) before and after treatment by treatment condition and outcome changes

<table>
<thead>
<tr>
<th></th>
<th>Errorless learning GMT</th>
<th>Conventional GMT</th>
<th>Main eff time</th>
<th>Main eff condition</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre Post</td>
<td>Pre Post</td>
<td>F  P</td>
<td>F  P</td>
<td>F  P</td>
</tr>
<tr>
<td>Executive function</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Response generation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFT</td>
<td>31.35 (7.29) 27 32.20 (7.87) 27</td>
<td>32.71 (9.69) 24 31.38 (9.79) 24</td>
<td>0.08</td>
<td>0.78</td>
<td>0.01</td>
</tr>
<tr>
<td>LFT</td>
<td>26.26 (8.74) 28 28.86 (9.57) 28</td>
<td>27.42 (9.58) 23 27.74 (9.21) 23</td>
<td>1.94</td>
<td>0.17</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Response inhibition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Go/no-go</td>
<td>678.92 (91.39) 25 656.52 (133.80) 25</td>
<td>642.25 (134.31) 24 639.08 (125.08) 24</td>
<td>0.78</td>
<td>0.38</td>
<td>0.72</td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSET</td>
<td>4.00 (1.76) 28 4.71 (1.51) 28</td>
<td>4.54 (1.53) 24 4.96 (1.33) 24</td>
<td>8.14</td>
<td>0.006*</td>
<td>1.05</td>
</tr>
<tr>
<td>Zoo map</td>
<td>5.33 (4.54) 27 8.44 (6.58) 27</td>
<td>7.30 (4.79) 23 10.78 (4.75) 23</td>
<td>17.42</td>
<td>&lt;0.001*</td>
<td>2.88</td>
</tr>
<tr>
<td>Working memory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LNS</td>
<td>7.39 (3.11) 28 8.43 (3.01) 28</td>
<td>8.88 (3.23) 24 9.42 (2.87) 24</td>
<td>5.27</td>
<td>0.03</td>
<td>2.52</td>
</tr>
<tr>
<td>Concept shifting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brixton</td>
<td>34.70 (7.18) 27 36.67 (9.15) 27</td>
<td>37.75 (6.91) 24 36.37 (9.95) 24</td>
<td>0.06</td>
<td>0.82</td>
<td>0.48</td>
</tr>
<tr>
<td>Memory</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RBMT (z-score)</td>
<td>51.33 (10.50) 6 52.00 (9.88) 6</td>
<td>47.00 (2.92) 5 50.00 (6.40) 5</td>
<td>2.61</td>
<td>0.11</td>
<td>0.06</td>
</tr>
<tr>
<td>Attention &amp; concentration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alertness</td>
<td>341.96 (97.58) 25 330.04 (147.03) 25</td>
<td>325.26 (202.58) 23 353.83 (221.69) 23</td>
<td>0.23</td>
<td>0.64</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Notes: CFT = Category Fluency Test; LFT = Letter Fluency Test; Go/no-go = Go/no-go, subtask TAP 2.1 (median); MSET = Modified Six Elements Test; Zoo map = Zoo map test, subtask of Behavioural Assessment of the Dysexecutive Syndrome; LNS = Letter Number Sequencing, subtask of Wechsler Adult Intelligence Scale-third edition; Brixton = Brixton Spatial Anticipation Test; RBMT = Rivermead Behavioural Memory test (-third edition); Alertness = Alertness, subtask TAP 2.1 (median); F and P values represent the main effects of time (baseline, post intervention) and condition (errorless learning GMT, conventional GMT) and the interaction effect between condition and time. P values ≤0.01 were considered statistically significant.
Table 2
Mean (SD) for questionnaires (subjective cognitive functions) before and after treatment by treatment condition and outcome changes

<table>
<thead>
<tr>
<th></th>
<th>Errorless learning GMT</th>
<th>Conventional GMT</th>
<th>Main eff time</th>
<th>Main eff condition</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
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<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>F P</td>
</tr>
<tr>
<td>Cognitive complaints CFQ</td>
<td>87.07 (14.42) 29</td>
<td>88.72 (11.23) 29</td>
<td>82.63 (15.36) 24</td>
<td>87.17 (14.02) 24</td>
<td>5.05 0.03 0.72 0.40 1.10 0.30</td>
</tr>
<tr>
<td>Executive behavioural problems DEX patient</td>
<td>27.59 (11.15) 29</td>
<td>25.38 (9.017) 29</td>
<td>27.87 (12.61) 24</td>
<td>25.67 (13.56) 24</td>
<td>2.75 0.10 0.01 0.92 &lt;0.01 1.00</td>
</tr>
<tr>
<td></td>
<td>29.62 (11.73) 26</td>
<td>25.77 (13.21) 26</td>
<td>30.09 (12.21) 23</td>
<td>26.61 (14.13) 23</td>
<td>7.97 0.007* 0.04 0.85 0.02 0.89</td>
</tr>
<tr>
<td></td>
<td>2.27 (15.34) 26</td>
<td>-0.31 (12.16) 26</td>
<td>1.09 (13.36) 22</td>
<td>0.77 (13.20) 22</td>
<td>0.85 0.36 0.00 0.99 0.51 0.48</td>
</tr>
<tr>
<td>Self-reported executive function EFI</td>
<td>95.89 (9.43) 27</td>
<td>98.04 (9.57) 27</td>
<td>91.17 (10.13) 24</td>
<td>96.79 (12.55) 24</td>
<td>13.58 0.001* 1.19 0.28 2.72 0.11</td>
</tr>
<tr>
<td></td>
<td>23.35 (5.51) 20</td>
<td>24.65 (4.26) 20</td>
<td>24.62 (3.58) 21</td>
<td>24.67 (3.50) 21</td>
<td>1.22 0.28 0.29 0.59 1.06 0.31</td>
</tr>
<tr>
<td>Observed executive function EOS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical function</td>
<td>24.54 (4.30) 28</td>
<td>25.04 (4.14) 28</td>
<td>23.67 (5.24) 24</td>
<td>0.91 0.35 0.70 0.41 0.33 0.57</td>
</tr>
<tr>
<td></td>
<td>Social function</td>
<td>6.79 (2.08) 28</td>
<td>7.39 (1.87) 28</td>
<td>6.74 (2.18) 24</td>
<td>4.28 0.04 0.11 0.74 0.32 0.58</td>
</tr>
<tr>
<td></td>
<td>Physical role</td>
<td>5.43 (1.43) 28</td>
<td>5.96 (1.60) 28</td>
<td>5.43 (1.70) 23</td>
<td>1.02 0.32 0.62 0.44 1.95 0.17</td>
</tr>
<tr>
<td></td>
<td>Emotional role</td>
<td>4.50 (1.37) 28</td>
<td>5.00 (1.25) 28</td>
<td>4.70 (1.36) 23</td>
<td>3.43 0.07 0.03 0.86 0.53 0.47</td>
</tr>
<tr>
<td></td>
<td>Mental health</td>
<td>20.82 (4.49) 28</td>
<td>22.25 (2.96) 28</td>
<td>21.78 (4.13) 23</td>
<td>3.03 0.09 0.08 0.78 2.38 0.13</td>
</tr>
<tr>
<td></td>
<td>Vitality</td>
<td>14.68 (4.01) 28</td>
<td>15.36 (3.23) 28</td>
<td>12.87 (3.59) 23</td>
<td>3.79 0.06 3.08 0.09 0.11 0.74</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>44.89 (10.18) 28</td>
<td>49.00 (10.22) 28</td>
<td>48.13 (12.60) 23</td>
<td>0.96 0.02 0.02 0.89 4.80 0.03</td>
</tr>
<tr>
<td></td>
<td>Health perception</td>
<td>17.86 (2.90) 28</td>
<td>17.43 (2.56) 28</td>
<td>17.00 (2.91) 23</td>
<td>0.07 0.80 0.51 0.48 0.61 0.44</td>
</tr>
<tr>
<td></td>
<td>Health change</td>
<td>3.39 (1.42) 28</td>
<td>3.57 (1.10) 28</td>
<td>2.79 (1.22) 24</td>
<td>0.78 0.38 4.36 0.04 0.02 0.89</td>
</tr>
</tbody>
</table>

Notes: CFQ = Cognitive Failures Questionnaire; DEX = Dysexecutive Questionnaire; EFI = Executive Function Index; EOS = Executive Observation Scale. F and P values represent the main effects of time (baseline, post intervention) and condition (errorless learning GMT, conventional GMT) and the interaction effect between condition and time. P values ≤0.01 were considered statistically significant.

Table 3
Mean (SD) for reported quality of life before and after treatment by treatment condition and outcome changes

<table>
<thead>
<tr>
<th></th>
<th>Errorless learning GMT</th>
<th>Conventional GMT</th>
<th>Main eff time</th>
<th>Main eff condition</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>F P</td>
</tr>
<tr>
<td>Physical function</td>
<td>24.54 (4.30) 28</td>
<td>25.04 (4.14) 28</td>
<td>23.67 (5.24) 24</td>
<td>23.79 (5.16) 24</td>
<td>0.91 0.35 0.70 0.41 0.33 0.57</td>
</tr>
<tr>
<td>Social function</td>
<td>6.79 (2.08) 28</td>
<td>7.39 (1.87) 28</td>
<td>6.74 (2.18) 24</td>
<td>7.09 (2.15) 24</td>
<td>4.28 0.04 0.11 0.74 0.32 0.58</td>
</tr>
<tr>
<td>Physical role</td>
<td>5.43 (1.43) 28</td>
<td>5.96 (1.60) 28</td>
<td>5.43 (1.70) 23</td>
<td>5.35 (1.67) 23</td>
<td>1.02 0.32 0.62 0.44 1.95 0.17</td>
</tr>
<tr>
<td>Emotional role</td>
<td>4.50 (1.37) 28</td>
<td>5.00 (1.25) 28</td>
<td>4.70 (1.36) 23</td>
<td>4.91 (1.24) 23</td>
<td>3.43 0.07 0.03 0.86 0.53 0.47</td>
</tr>
<tr>
<td>Mental health</td>
<td>20.82 (4.49) 28</td>
<td>22.25 (2.96) 28</td>
<td>21.78 (4.13) 23</td>
<td>21.87 (4.39) 23</td>
<td>3.03 0.09 0.08 0.78 2.38 0.13</td>
</tr>
<tr>
<td>Vitality</td>
<td>14.68 (4.01) 28</td>
<td>15.36 (3.23) 28</td>
<td>12.87 (3.59) 23</td>
<td>13.83 (3.93) 23</td>
<td>3.79 0.06 3.08 0.09 0.11 0.74</td>
</tr>
<tr>
<td>Pain</td>
<td>44.89 (10.18) 28</td>
<td>49.00 (10.22) 28</td>
<td>48.13 (12.60) 23</td>
<td>46.57 (13.16) 23</td>
<td>0.96 0.02 0.02 0.89 4.80 0.03</td>
</tr>
<tr>
<td>Health perception</td>
<td>17.86 (2.90) 28</td>
<td>17.43 (2.56) 28</td>
<td>17.00 (2.91) 23</td>
<td>17.22 (3.83) 23</td>
<td>0.07 0.80 0.51 0.48 0.61 0.44</td>
</tr>
<tr>
<td>Health change</td>
<td>3.39 (1.42) 28</td>
<td>3.57 (1.10) 28</td>
<td>2.79 (1.22) 24</td>
<td>2.92 (1.21) 24</td>
<td>0.78 0.38 4.36 0.04 0.02 0.89</td>
</tr>
</tbody>
</table>

Notes: RAND-36 = RAND 36-item Short Form Health Survey. F and P values represent the main effects of time (baseline, post intervention) and condition (errorless learning GMT, conventional GMT) and the interaction effect between condition and time. P values ≤0.01 were considered statistically significant.
practice effects into account, using the computer program RegBuild_MR.exe (Crawford, Garthwaite, Denham, & Chelune, 2012; http://homepages.abdn.ac.uk/j.crawford/pages/dept/RegBuild_MR.htm) and test-retest data (means, standard deviations and correlations) derived from the test’s manuals. The percentage of patients who showed a reliable improvement was calculated using the RCI results.

3. Results

Sixty of the initially included 67 participants completed the trial and received errorless (n = 30) or conventional GMT (n = 30). Treatment effects on the primary and secondary outcome measures have been reported elsewhere (Bertens et al., 2015). Briefly, everyday task performance (primary outcome) improved significantly more after errorless GMT compared to conventional GMT (p = 0.006, Cohen’s $d = 0.87$). Goal attainment scored by the trainers showed also a superior effect of errorless GMT (secondary outcome). Demographic characteristics and type and duration of brain injury did not differ between the two groups, nor did objective and subjective cognitive function and quality of life at baseline (Bertens et al., 2015).

Table 1 shows the neuropsychological test scores at baseline and post-training. No significant group by time interaction effects were found. Overall, participants improved significantly on the MSET (F(1,50) = 8.14, $p = 0.006$, $\eta_p^2 = 0.14$) and Zoo Map test (F(1,48) = 17.42, $p < 0.001$, $\eta_p^2 = 0.27$). RCI analyses showed that none of the participants reliably improved on the MSET after training. On the Zoo Map test, 20.0% of the patients (errorless GMT: 18.5%; conventional GMT: 21.7%) improved reliably after training.

Furthermore, subjective cognitive complaints did not interact with type of treatment either (Table 2). Overall, executive everyday function as reported by the patients increased (EFI: F(1,49) = 13.58, $p = 0.001$, $\eta_p^2 = 0.22$) and executive behavioral problems reported by proxies decreased (DEX: F(1,47) = 7.97, $p = 0.007$, $\eta_p^2 = 0.15$). No significant changes on quality of life were found (Table 3).

4. Discussion

The current study did not reveal beneficial effects of errorless GMT on cognitive function and quality of life compared to conventional GMT. Independent of treatment type, improvements on the MSET and the Zoo Map test were found. A reliable improvement, however, was only found for the Zoo Map scores in 20% of the patients. The remaining executive tests did not reliably improve. Improvement on the Zoo Map test could reflect a transfer effect to an untrained, yet ecologically valid executive task. A previous GMT study in brain-injured patients (Levine et al., 2011) also found transfer to an untrained Go/No-go task (SART) and a visuospatial planning task (D-KEFS Tower Test).

With respect to subjective cognitive complaints, no differences were found between the errorless and the conventional GMT groups after treatment. In general, patients reported better executive function in daily living after both treatments, whereas proxies reported a decrease in executive behavioral problems. This is in agreement with the results of previous studies, which also showed that proxies (Miottto, Evans, de Lucia, & Scaff, 2009; Schweizer et al., 2008; Spikman, Boelen, Lamberts, Brouwer, & Fasotti, 2010) and therapists (Spikman et al., 2012) reported less complaints after GMT. However, in our study post-treatment improvements were not found on all subjective cognitive measures.

Finally, no significant changes on self-reported quality of life were found. This indicates that treatment and the improvement of specific daily activities did not affect the patients’ wellbeing in either treatment condition. Possibly, the time to benefit from possible training gains was too limited, as the assessment took place directly after training. Longer follow-up assessments could overcome this particular issue. Another limitation of our study design is that no untrained control group was included. The reported improvements could, as a result, be ascribed to extraneous variables such as natural recovery. However, by only including brain-injured patients in the chronic phase, natural recovery was not expected.

In conclusion, extending our previous findings (Bertens et al., 2015), we argue that errorless GMT contributes to a more effective training of daily activities, yet does not show additional transfer to untrained executive tests nor affects subjective performance and quality of life to a greater extent than conventional GMT. Irrespective of treatment, we observed improvements, albeit limited ones, concerning executive function and complaints, which are in line with previous research. The combination of errorless learning and GMT is a valuable contribution
to cognitive rehabilitation enhancing performance of specific everyday tasks.

Acknowledgements

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Conflict of interest

None declared.

References


