Augmented Dyadic Therapy Boosts Recovery of Language Function in Patients With Nonfluent Aphasia

A Randomized Controlled Trial

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Background and Purpose—Evidence suggests that therapy can be effective in recovering from aphasia, provided that it consists of socially embedded, intensive training of behaviorally relevant tasks. However, the resources of healthcare systems are often too limited to provide such treatment at sufficient dosage. Hence, there is a need for evidence-based, cost-effective rehabilitation methods. Here, we asked whether virtual reality-based treatment grounded in the principles of use-dependent learning, behavioral relevance, and intensity positively impacts recovery from nonfluent aphasia.

Methods—Seventeen patients with chronic nonfluent aphasia underwent intensive therapy in a randomized, controlled, parallel-group trial. Participants were assigned to the control group (N=8) receiving standard treatment or to the experimental group (N=9) receiving augmented embodied therapy with the Rehabilitation Gaming System for aphasia. All Rehabilitation Gaming System for aphasia sessions were supervised by an assistant who monitored the patients but did not offer any elements of standard therapy. Both interventions were matched for intensity and materials.

Results—Our results revealed that at the end of the treatment both groups significantly improved on the primary outcome measure (Boston Diagnostic Aphasia Examination: control group, P=0.04; experimental group, P=0.01), and the secondary outcome measure (lexical access—vocabulary test: control group, P=0.01; experimental group, P=0.007). However, only the Rehabilitation Gaming System for aphasia group improved on the Communicative Aphasia Log (P=0.01). The follow-up assessment (week 16) demonstrated that while both groups retained vocabulary-related changes (control group, P=0.01; experimental group, P=0.007), only the Rehabilitation Gaming System for aphasia group showed therapy-induced improvements in language (P=0.01) and communication (P=0.05).

Conclusions—Our results demonstrate the effectiveness of Rehabilitation Gaming System for aphasia for improving language and communication in patients with chronic aphasia suggesting that current challenges faced by the healthcare system in the treatment of stroke might be effectively addressed by augmenting traditional therapy with computer-based methods.

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Key Words: aphasia ■ embodied training ■ neurological rehabilitation ■ virtual reality

Twenty percent of poststroke patients display nonfluent aphasia at the chronic stage (≥6-month poststroke). Affected individuals may experience changes in language processing and learned nonuse,[1] resulting in social exclusion, depression, a compromised quality of life, as well as limited language recovery.[2] Although clinical evidence suggests that therapy can facilitate rehabilitation, provided that it consists of socially embedded, intensive training of behaviorally relevant goal-oriented tasks,[1,3] the resources of most healthcare systems are too limited to promote such methods at sufficient dosage.[4,5] Hence, there is a need for evidence-based, cost-effective rehabilitation techniques for improving the condition of people with aphasia and maximizing their self-efficacy.

Several studies suggest that computer-based methods could be beneficial for providing rehabilitation for poststroke aphasia patients.[6,7] Importantly, however, evidence from the RCTs

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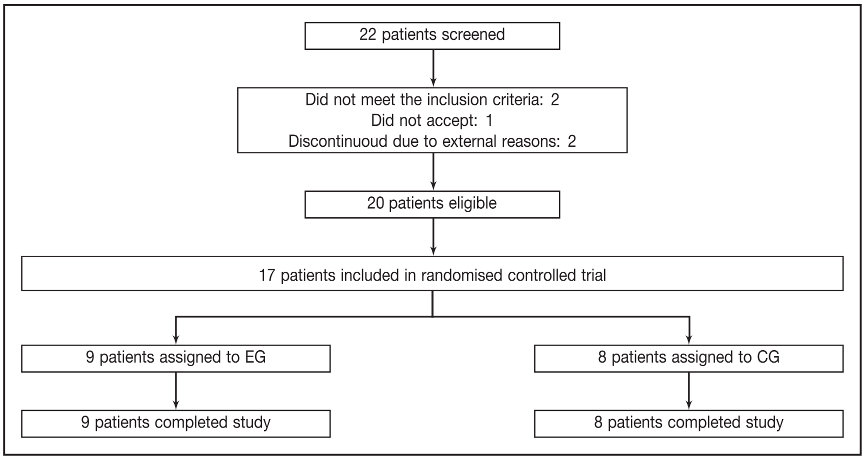

Figure 1. Flow diagram. CG indicates control group; and EG, experimental group.

(Randomized Controlled Trials) supporting the implementation of such treatments in the clinic is still required. Here, we pose the question of whether embedding aphasia rehabilitation in the context of embodied peer-to-peer interaction grounded in the principles of use-dependent learning, behavioral relevance, and intensity[8,9] positively impacts recovery. To the best of our knowledge, we performed the first RCT investigating the effectiveness of this approach for persisting nonfluent aphasia by using a virtual reality-based rehabilitative technique. The proposed therapy called the Rehabilitation Gaming System for aphasia (RGSa) provides lexical and syntactic training in a multimodal, goal-oriented manner within a context of dyadic peer-interaction.[8,9] We hypothesized that RGSa training would lead to a comparable recovery of language functions as a standard speech and language therapy (SLT).

Methods

The data that support the findings of this study are available from the corresponding author upon request. The RCT was approved by the local ethics committee and registered on clinicaltrials.gov.

Seventeen patients (Figure 1) with chronic nonfluent aphasia provided their consent and participated in a parallel-group RCT. We used computer-generated stratified randomization to assign the participants to the experimental group (EG; N=9) or control group (CG; N=8). Clinical and demographic sample characteristics are presented in Table I in the online-only Data Supplement.

The RGSa (Figure 2A) had a form of dyadic peer-to-peer language training protocol inspired by intensive language-action therapy.[10] Two patients were sat in front of each other facing their respective screens. They interacted by performing planar arm movements which were tracked and mapped onto the avatars' upper limbs providing embodiment and allowing the interaction with virtual objects (Figure 2B and 2C). The paradigm required engagement in everyday-like communication acts by requesting objects, or handing them over when requested by the other player.[10] There was a set of 3 objects simultaneously available for selection. Object selection for both request and response required the players to place the hand over the target object for 3 seconds. The interaction was based on turns (Figure 2D), and the goal for each patient and each session was to collect 36 objects. The materials consisted of 120 three-dimensional (3D) objects (Figure 2B and 2C). To promote the activation of the language network, the RGSa protocol allowed using gestures and self-cueing strategies which accompanied but did not substitute verbal communication.[11] The RGSa sessions were supervised by a therapy assistant who monitored possible technological or communication difficulties. Importantly, the assistant did not offer any additional services.

In the CG, patients received standard SLT targeting specific linguistic deficits in a therapist-patient setting. The therapy aimed at training naming, repetition, spelling, and articulation. The intensity and frequency of the intervention in both groups were matched: 8 weeks, 5 days per week. The duration of each session was 30 to 40 minutes. Similarly, both groups used the same training materials:

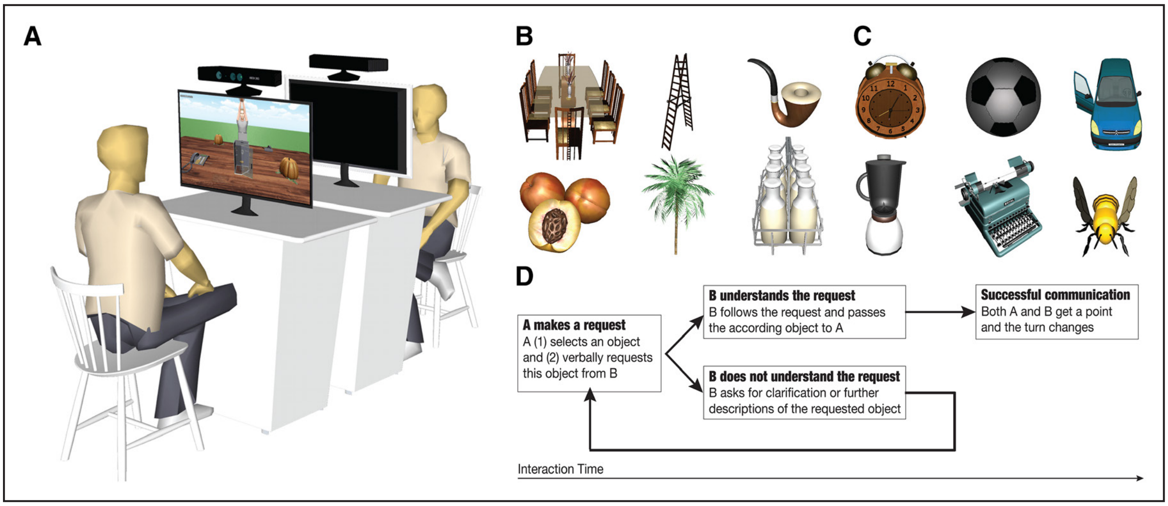

Figure 2. Setup and materials. **A**, Therapeutic setting. **B** and **C**, Example of materials. Items without (**B**) and with (**C**) semantically related sounds. Illustration of the dynamics of the Rehabilitation Gaming System for aphasia interaction, possible moves, and speech acts (**D**).

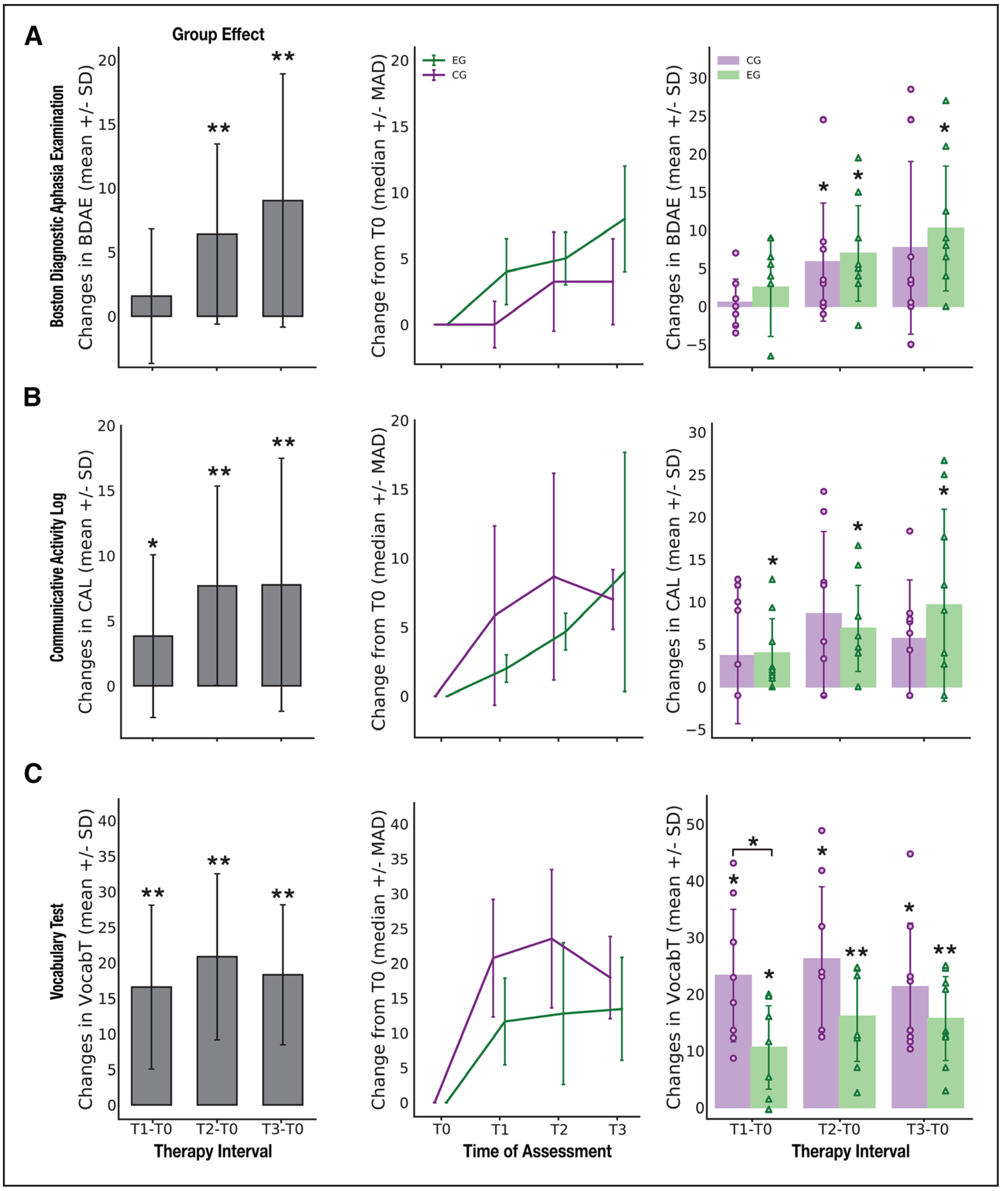

Figure 3. Clinical outcomes. Boston Diagnostic Aphasia Examination (BDAE; **A**), Communicative Activity Log (CAL; **B**), and vocabulary test (VocabT; **C**). **Left**, Whole-group effect (N=17). **Center** and **Right**, Changes from baseline at each time step for experimental group (EG) and control group (CG). Triangles and circles indicate individual-patient data. MAD indicates median absolute deviation. **P*<0.05 and ***P*<0.01: Wilcoxon signed-rank and Mann-Whitney *U* test, respectively.

EG-122 3D objects (Figure 2B and 2C) and CG-122 images presented in the form of cards.

The primary outcome measure was the performance on chosen subtests from the Boston Diagnostic Aphasia Examination which measures language function in people with language disorders. The secondary outcome measures included the Communicative Activity Log evaluating communicative frequency and effectiveness in everyday life, the vocabulary test assessing the lexical access and verbal execution of the trained stimuli, Fugl-Meyer Upper Extremity Scale measuring the motor impairment of the hemiplegic arm, and the interaction times (Figure 2D) extracted from the RGSa system. The corresponding data were collected at baseline (T0), week 4 (T1), week 8 (end of intervention; T2), and the follow-up (week 16; T3). During the follow-up period, patients could not continue SLT or receive any therapy from third parties. Detailed information about the methods as well as the outcome measures is available in the Methods in the online-only Data Supplement.

We used the Friedman test to compare the overall effect of the treatments within groups and the Wilcoxon signed-rank test for post hoc statistical analyses. The Mann-Whitney *U* test was performed to identify between-group differences.

Results

The homogeneity of the groups at baseline was confirmed for all measures (Table II in the online-only Data Supplement).

Based on the Boston Diagnostic Aphasia Examination (Figure 3A; Tables III and IV in the online-only Data Supplement), an increase in language performance was found for both groups (N=17; *P*<0.001). Specifically, we observed changes in T2−T0 and T3−T0 (*P*=0.001 and *P*=0.002, respectively). The within-group analysis showed differences for both CG (*P*=0.04) and EG (*P*=0.006). The post hoc analysis for EG demonstrated changes at T2−T0 (*P*=0.01), T3−T0 (*P*=0.01), and T3−T1 (*P*=0.01). For CG, we found changes at T2−T0 (*P*=0.04), and T2−T1 (*P*=0.04). No differences in

Boston Diagnostic Aphasia Examination changes were found between groups.

Communicative Activity Log analysis (Figure 3B; Table III in the online-only Data Supplement) showed improvement for both groups (P=0.01) at each time step (T1: P=0.01; T2: P=0.002; and T3: P=0.009). The within-group analyses yielded changes in EG (P=0.02), in particular, an increase at T1−T0, T2−T0, and T3−T0 (P=0.01, P=0.01, and P=0.05, respectively) as well as T2−T1 (P=0.01). However, we found neither effects for CG nor significant differences between the groups.

The vocabulary test analysis (Figure 3C; Table III in the online-only Data Supplement) revealed an improvement at the whole-group level (N=17; P<0.001) at each time step (T1: P<0.001; T2: P<0.001; and T3: P<0.001). The within-group analysis demonstrated differences for EG (P<0.001) and CG (P=0.003). For EG, the scores differed between T0 and T1, T2, and T3 (P=0.01, P=0.007, and P=0.007, respectively), between T1 and T2 (P=0.007), and between T1 and T3 (P=0.007). For CG, we found changes from T0 at T1, T2, and T3 (P=0.01, P=0.01, and P=0.01, respectively), from T1 at T2 (P=0.01) and T3 (P=0.01), and from T2 at T3 (P=0.04). Additionally, the between-group analysis showed a significant difference between EG and CG at T1 (P=0.02).

Based on the Fugl-Meyer Upper Extremity Scale (Table III in the online-only Data Supplement), we found changes for the 2 groups at T1 (P=0.04) and T2 (P=0.02). The analysis yielded an effect of time in EG at T1 (P=0.04) and T2 (P=0.04). No differences were found for CG (P=0.6). We further report differences at T1−T0, T2−T0, and T3−T0 between the groups (P<0.009, P<0.04, and P<0.03, respectively).

Finally, interaction times decreased for all patients in EG over the therapy interval. In particular, linear regression revealed a relationship between the averaged interaction times and the therapy days (R=−0.38, P=0.01). Moreover, the Pearson correlation yielded a significant relationship between interaction times and vocabulary test (R=−0.46, P<0.001).

Discussion

We explored the effects of RGSa on functional recovery of language and communication in patients with nonfluent aphasia relative to standard SLT. Our results revealed that, immediately after treatment, both groups improved in terms of speech production, auditory comprehension, communicative effectiveness in everyday life, and lexical access. At the follow-up, both groups retained the vocabulary-related changes. However, only the RGSa maintained the language improvements.

First, the experimental design controlled for the influence of training intensity and duration, clinical setting, therapy materials, as well as the number of utterances. However, the 2 groups differed with respect to the training components (embodied, sensorimotor, goal-oriented training versus linguistic, and impairment-focused), content (verbal communication versus naming and repetition), and the nature of the interaction (peer-peer versus therapist-patient). Additionally, in the RGSa group, the communication consisted of the contextualized peer-to-peer training and, at times, exchanges with the therapy assistant. Despite the methodological heterogeneity, however, both methods were beneficial for language improvement and retention of changes in the lexical access. Notably, CG performed significantly better than RGSa on vocabulary test at T1, and RGSa outperformed CG on Communicative Activity Log at each assessment point. These results may suggest that while the SLT promoted lexical access and verbal execution of the target stimuli, RGSa possibly induced higher frequencies of language use. Moreover, only the RGSa group showed significant maintenance of those improvements. Future studies should systematically investigate the contribution of the specific training components of the RGSa on functional and structural recovery as well as their short- and long-term effects with a higher sample size.

Second, RGSa allowed the use of both arms and the execution of gestures serving self-cueing strategies while preventing compensatory mechanisms. This design principle is grounded on the evidence of bidirectional connections between the motor and language systems.[11] Specifically, it supports the notion that enhanced neuronal activity during language processing through simultaneous execution of goal-directed and language-associated gestures might facilitate language performance, and vice-versa. Indeed, we found that EG, but not CG, showed significant differences in Fugl-Meyer Upper Extremity Scale during the intervention. Although these differences do not seem to reach clinical relevance,[12] they show a positive trend suggesting that RGSa might also promote the recovery of motor function. Based on the same principle, future studies shall investigate the reverse effect, specifically, the integration of action-embedded language use in the recovery of motor disorders.

Overall, present results emphasize the potential of RGSa for the improvement and long-term stability of the language training effects. From a healthcare perspective, RGSa might be integrated into the clinical practice allowing people with aphasia access to continuous and self-paced training at the chronic stage of the disease.

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Disclosures

P. Verschure (ICREA) declares to be a founder and interim CEO of Eodyne SL, which aims at bringing scientifically validated neurorehabilitation technology to society. The other authors report no conflicts.

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