Rehabilitating numerical processing difficulties in adults with aphasia

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Introduction

Difficulties with numerical processing and calculation are frequently observed in adults with aphasia,[1] for example, individuals may have difficulties with transcoding (e.g. they are unable to name numbers aloud, or at least not without counting on their fingers) and counting, as well as simple and complex calculation. These problems can cause significant emotional and social impact in activities of everyday life.[2] Despite this, intervention to address these difficulties clinically is rarely undertaken.

This study aimed to explore the effectiveness of a novel intervention for numerical processing difficulties in two adults with aphasia. The SWAN therapy game addresses numeracy difficulties by exploiting gaming technology to encourage mass practice of foundational number language: counting and transcoding.

Methods

Participants

Table 1. Participant demographic information and pre-intervention number processing skills

Participant	Age	Gender	Education	Previous employment	WAB AQ	WAB Aphasia Type	Baseline number processing: Identification	Reading	Writing	Count forward	Count backward
George	37	M	Postgraduate studies	Managing Director	78.8	Anomic	0.35	0.25	0.20	0.43	0.06
Connie	63	F	College/university	Nurse	85.5	Anomic	0.88	0.85	0.90	0.54	0.41

George:

- mild anomic aphasia, presenting with minor problems in auditory comprehension and word finding
- **poor number processing skills**, including tasks requiring production and comprehension
- unable to carry out calculation tasks or a functional assessment

Connie:

- mild anomic aphasia, with some word-finding difficulties
- a mixed profile of number processing skills, with **relative strengths in transcoding but poor counting**
- errors with sequences in the middle range of numbers, and particularly at **decade boundaries** (e.g. "59-50…60-61"; "82-81-79-78")

Intervention

In SWAN, the user creates sequences by selecting tiles; each time a tile is selected its name is played.

There are two key components to the intervention:

- **Developmental stages**[3]: Number sequences in the game increase in range and complexity, corresponding to the pattern observed in children's learning
- **Mass practice**[4]: Repeated opportunities for users to link each Arabic numeral with its phonological form, exploiting the benefits of multiple opportunities to practise

Figure 1. SWAN screenshot

Outcome measures

Assessment of proximal skills:
- Transcoding (ID, reading, writing)
- Counting (forwards, backwards)

Assessment of distal skills:
- Addition (with/without carrying)
- Subtraction (with/without carrying)

- Functional numeracy test[5]
- Control assessment: Bespoke analogical reasoning task

All assessments were completed online over Zoom.

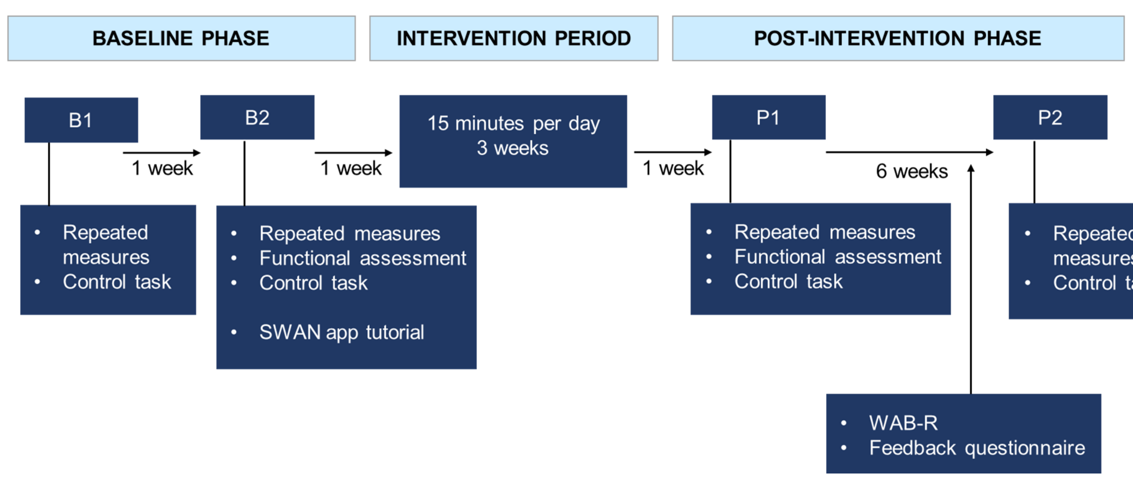

Figure 2. Intervention study design

Results

Response to intervention

Treatment-related improvement in performance was analysed using **item-based weighted statistics** (WEST, Howard et al., 2015),[6] designed for use in single case intervention studies.

George:

Significant improvement in **number ID** and **counting backwards**
- Counting backwards in **single digits** ("9-8-7-6-5") consistent after therapy
- A small gain in counting backwards in the **teens** (completing "14-13" for the sequence 14-13-12-11-10) was not maintained at follow-up
- No improvements in higher number ranges

Connie:

Significant improvement in **number reading**, **counting forward** and **addition**; improvement in **counting backwards** was marginally significant
- Production of sequences at **decade boundaries** was greatly improved
- Improvements in **addition** reflect completion of more problems within the 60-second limit

Gameplay data

Table 2. Summary of key gameplay variables for the participants

	Maximum level reached	Number of repeated levels	Mean sequence proportion	Mean score	Mean time per tile (secs)	Mean number of errors per level	Dosage
George	71	0	0.97	0.96	2.97	8.59	08:35:41
Connie	110	4	0.92	0.87	1.09	6.75	05:14:00

We examined participants' gameplay in relation to specific obstacles observed pre-therapy and which appear to have been resolved after intervention. Both individuals reveal **multiple and largely error-free completions of sequences that were problematic pre-therapy**.

George

- George's few errors reflect **faults in gameplay rather than failure of sequence** (see fig 3). The design of the game meant that he received:
  - 15 levels of input for descending sequences of single digits
  - 5 levels of descending teens

Figure 3. Example of George's gameplay. Red arrows: sequences of selections registered as errors not complete sequences. Green: complete sequence registered. Circled tiles: start of a sequence.

Connie

- Problematic decade boundaries were **largely completed without error** in the game, e.g. the boundary 59-60 was completed in 19/22 sequences. The 3 errors included:
  - 1 error of sequence ("52-53-54-55-56-57-58-59-69")
  - 1 incomplete sequence (see fig 4)

Figure 4. Example of Connie's gameplay, showing forward sequence creation.

Discussion

- Findings suggest our game-based intervention is an effective tool in **providing repeated and concentrated input** for improving basic numerical processing.
- **Multiple opportunities to practise problematic sequences** may have helped the participants to produce them more easily. Practice was largely free from errors of sequence. SWAN is designed to maximise opportunity to select the correct number in sequence: it may therefore be viewed as acting as a **scaffold**.
- Practice with SWAN may facilitate **better access to numerals and the count sequence**, resulting in greater fluency in arithmetic tasks.
- Neither participant made significant gains on the functional numeracy assessment: **more targeted practice** may be required which places the abilities being trained within **daily life contexts**.

References

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