

# Investigating the effectiveness of “SWAN”, a digital game for remediation of acalculia in adults with aphasia

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## Introduction

People with aphasia often report that they are unable to understand and use mathematical information. Consequently, they have difficulties doing some of the simplest tasks such as saying their telephone number or calculating change – tasks most of us take for granted. Low levels of numeracy skills can impact on all aspects of an individual’s life and can affect their confidence and self-esteem. Several studies have shown that adults with aphasia have difficulties performing operations with symbolic formats such as Arabic numerals, and that they have deficits in transcoding and counting (Lemer, Dehaene, Spelke & Cohen, 2003; Cappelletti, Butterworth and Kopelman, 2012). Some evidence suggests that automatic counting is better retained than non-automatic counting, where numbers are named in non-consecutive order (Lum and Ellis, 1999). When asked to name a number out of order, they can sometimes do this accurately, but they need to count up the sequence starting from one.

The current study is a case series, which aims to evaluate the effectiveness of a digital intervention designed to provide intensive training in counting and sequencing skills. The primary goals of the study were to determine whether performance improved significantly between the pre- and post-training periods and to identify which numerical skills were most sensitive to training.

## Methods

### *Participants*

Fifteen adults (12 men and 3 women), aged 44 – 85 years, with different types and severity of aphasia, were recruited. They all reported difficulties with counting and number processing.

### *Outcome Measures*

Participants were tested on a battery of linguistic and numerical tasks before and after three weeks of home training with “SWAN”. A control task, nonword reading aloud, was also completed to exclude the possibility of spontaneous recovery. The numerical tasks tested included verbal counting, transcoding, calculations, functional numeracy and symbolic and nonsymbolic number comparison, although not all of participants completed all of the tasks. A postgame questionnaire evaluated participants' perceptions of the game.

We hypothesized that participants would show the largest improvement on tasks that depended on counting and sequencing and show little or no improvement in calculation, as this skill was not directly targeted by the intervention.

## ***Intervention***

The intervention (“SWAN”: Sequencing Words and Numbers) is based on research in normal child development which suggests that learning the number-word sequence involves at least five different levels (Fuson, 1988). This includes the unbreakable list level where the sequence can only be produced by starting at the beginning, the breakable chain level where parts of the chain can be produced starting from arbitrary points and the final bidirectional chain level where words can be produced in either direction. It is possible that adults with aphasia have reverted back to a simpler level of counting and need to reacquire more advanced sequence skills if they are to produce numbers easily.

“SWAN” is a game-based intervention delivered via tablet computer that allows players to work through the different levels of number-word sequencing, as well as an increasingly wider range of numbers. It was designed to be fun and positive reinforcement was provided in order to maintain attention and motivation. The game involves tapping on tiles to create a sequence of numbers, the longer the better. The software was also designed to emphasize the association between Arabic numerals and number words; the name of the number is said aloud each time a tile with an Arabic numeral is pressed.

Following a training session, participants were asked to play the game every day for a minimum of 15 minutes. They completed the intervention over the Christmas holiday, so that ongoing speech and language therapy would not confound the results.

## **Results**

None of the participants showed a significant improvement on the transcoding task. However, gains were made on the sequencing tasks. A significant improvement in accuracy was found across the group for the automatic sequencing task. Improvements were also observed in faster responses. Positive trends in accuracy were found for non-automatic sequencing tasks, with some individuals demonstrating significant improvements. Other participants, who scored at ceiling on these tasks, were quicker. Participants varied in their performance on the numeracy tasks with some improving their scores on the WRAT-3 (Wilkinson & Robertson 2006) as well as the functional numeracy task.

All participants apart from one remained stable across time points on the control task. This suggests that gains made in sequencing, calculation and number related skills when using SWAN were not due to general recovery.

Qualitative data collected on the feedback questionnaires indicated that all participants enjoyed playing the app, although some issues arose with confusion of the level instructions, touch sensitivity and the bonus mechanics.

## **Discussion**

The results showed that after using the game, adults made improvements on several tasks, suggesting that the intervention was successful in improving basic numerical processing. Responses were quicker and there was less reliance on nonverbal strategies. Improved accuracy was not always observed because some participants scored at ceiling on tests. Unexpected changes in the numeracy tasks may have been due to better number naming, which reduced cognitive load.

These results are only a first step in determining the effectiveness of SWAN. The generality and duration of the effects found need to be tested.

## References

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