

SUMMARY OF FINAL REPORT

Developing non-invasive therapeutic technology to improve motor coordination in cerebellar ataxias

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Background and aims:

In purposive activities a person has to control the closure of gaps between where they are now and where they want to be (e.g., the gap between their hand and a cup when reaching for it). Pilot work with a person with ataxia had demonstrated that reaching with a 'sonic movement guide' helped improve coordination. The sonic movement guide was a sound in which pitch glided upwards across an octave, producing a 'whoop' sound. The temporal form of the 'whoop' sound mimicked the temporal form of normal healthy movements, such as reaching, stepping and swaying. That is, the mathematical formula for generating a 'whoop' was the same as the formula describing healthy movements. Thus, by mimicking the form of the whoop sonic guide with their own movement, a person with ataxia might improve their movement in purposive exercises. To do this, the sonic guide is either played out-loud, or memorized by the person, who then plays it in their head. Improvements in movement control can be attributed to extra sensory information being made available to participants, particularly in situations where cerebellar damage may contribute to poor motor control.

The purpose of this project was to develop movement training programmes using sonic movement guides for people with ataxia to improve their movement control and hence their general health and quality of life. The researchers planned to use high-speed motion capture and force measurements to analyse movement in people with cerebellar ataxia and use these data to develop the training programmes. The programmes will be cost-effective and user-friendly and the intention is that they could be used by therapists for treating people with ataxia, and by clinicians for diagnostic purposes.

Results:

Experiment 1

Ten able-bodied participants, without ataxia, reached in time with sonic movement guides to a button in front of them, while the movement of their hand was monitored by motion-capture cameras. A 'whoop' guide and a sonic guide in which pitch increased at a steady rate were used. The results showed that the participants could couple their reaching movements to the 'whoop' guides, but were poorer at coupling to the sounds in which pitch changed at a steady rate. Therefore, the whoop sounds were judged to be more likely to be beneficial for rehabilitation programmes, and so were used in the following studies.

Experiment 2

The whoop sonic movement guides identified in experiment one were used in neuro-rehabilitative exercises in twenty people with ataxia. Participants were asked to sway from side to side; firstly without a sonic guide - as a baseline (condition one), secondly with a sonic guide (condition two) and thirdly whilst the participants generated the sounds of the sonic guides in their heads (condition three). The swaying was measured as an indication of balance and the jerkiness of the movement was measured as an indication of motor control (high levels of jerk are assumed to indicate poor levels of motor control). Of the 20 participants, 10 received the rehabilitative treatment and 10 were controls who received no intervention and swayed without sounds.

There was improvement in both groups; lower jerk scores, indicative of improved motor control, were recorded in condition three for both groups. The improvement in the control group is almost certainly down to practice as they had no sound intervention. Statistical analysis revealed that the improvement in the experimental group (group 1) was significant ($p < .001$), however no significant effect was found in the control group.

Statistical tests on performance of each individual were also performed. These revealed that in the experimental group, which was given sounds to move with, 60% of participants showed a significant improvement (30% showed no change and 10% performed worse) whilst in the control group, which did not hear sounds, only 10% showed improvement (60% showed no significant change and 30% performed worse).

The differences in these results can be attributed to the extra perceptual information provided through moving with the sonic guides. By following the sounds and then generating their own in the mind, people with ataxia are moving in smoother more controlled ways.

Furthermore, after completion of these experiments, the control group was given the sonic guide intervention and the results show that overall the group's movements were less jerky than before, suggesting an improvement in movement ($p < .05$).

Experiment 3

This experiment explored the ability of the intervention from experiment two to produce permanent core postural stability changes in people with ataxia.

A programme was set up using side to side and forwards and backwards sway exercises in conjunction with the sonic guides to improve balance. It was hoped that

the additional perceptual cueing embedded in the sonic guides would help people access these exercises with the correct form and levels of control needed to produce plastic changes at the neuronal level.

To test this, seven of the original experimental group returned to the laboratory every two weeks for the next two months. In between visits they were asked to spend five minutes each day swaying with the sonic guides as demonstrated during original testing. They were also asked to spend an additional five minutes swaying with the sounds 'in the head'.

Four out of the seven people who took part in the two month follow up showed significant improvements in core balance skills. It is difficult to ascertain how much of this is attributable to the sonic guides as clearly the balance exercises are the driver of any change.

Nonetheless it is believed that as shown in experiment two, the extra control and smoothness seen when sonic guides are used will have a positive impact on people's balance. To ascertain how much improvement would require a proper control group to use the exercises solely for the two month programme, but this was beyond the scope of this project.

Lay summary of the results:

Working closely with people with ataxia, we produced and tested user-friendly non-invasive therapeutic devices to help them improve their upright balance control, because this was their central concern. Controlling body sway in balance requires controlling the closure of the changing gap between the current position of the body and its desired end position, to avoid falling.

Damage to the cerebellum often comes with accompanying sensory impairment leading to poor motor control. So is it possible to augment the sensory information with sounds to help guide movement? It would make sense for the temporal form of the sounds to mimic the temporal form of normal healthy movement. Therefore we designed sounds in which the pitch moves upward across an octave in the same way as, eg, the hand moves when reaching for something, or the foot moves when stepping, or the body moves when swaying. What the moving pitch sounds like is 'whoop'. These whoop sounds were then tested in three experiments.

In the first experiment, we verified that able-bodied people could couple their reaching movements to the 'whoop' sounds, whereas they were poorer at coupling to sounds in which pitch simply increased at a steady rate.

In the second experiment we tested twenty people with ataxias to determine whether side-to-side body sway (the control of which is necessary for walking) is improved by using 'whoop' sounds. They were divided into two groups of ten: a 'whoop' group and a practice-only control group. Each person stood on forceplates, which recorded how their weight shifted as they swayed from side-to-side. For the 'whoop' group, in the first two trials there was no sound playing (condition one); in the next two trials they tried to sway side-to-side in time with a sequence of 'whoops' played over a loudspeaker (condition two); in the final two trials they tried to sway side-to-side in time with a sequence of 'whoops' which they imagined and played in their heads

(condition three). For the practice-only control group, conditions one, two and three were all the same; no sounds were played out loud or in their heads. Sway control was measured by the degree of jerkiness in the sway movements (measured from the forceplate data).

The results of experiment 2 were as follows: (i) The 'whoop' group showed a statistically significant reduction in jerkiness from condition one (pre-test) to Condition three ('whoops' playing in their head), whereas the control group, who were not given 'whoops' but simply practiced the side-to-side swaying, showed no significant difference between condition one and condition three. (ii) The change in jerkiness from condition one to condition three for individuals showed a similar pattern as for the groups. In the 'whoops' group, 60% of participants showed a significant reduction in jerkiness, 30% showed no significant change, and 10% performed significantly worse. The corresponding percentages for the control group were 10%, 60% and 30%.

In the third experiment, seven people with ataxias visited the lab every two weeks for two months, to test whether their balance improved over time. At each visit they were given practice with the 'whoops' as in the second experiment. In addition, they were asked to practice at home for five minutes per day with the 'whoops' sounding, and five minutes per day with the 'whoops' in their head. The degree of sway when free-standing was used to assess their balance performance. Over the two months, four of the seven participants showed significant improvement in this core balance skill (measured by the degree of sway when free-standing).

In sum, the 'whoops' movement guide can be useful for people with ataxias for improving their upright balance control. It seems likely that the same method could help them in improving other skills, such as reaching and grasping.

Benefits to people with ataxia arisen/likely to arise from this research:

We have shown that the 'whoops' movement guide can be useful for people with ataxias for improving their upright balance control. It seems likely that the same method could help them in improving other skills, such as reaching and grasping. They could be helped in movement training using the 'whoops' method, eg by a health professional, though as with any therapy they must also be prepared to practice at home.

Publications arisen from this project:

Papers will be written after the thesis is complete.

Conferences/ meetings where this research has been presented:

The research was presented by Lee in papers relating the theory underpinning the ataxia and other applied research (General Tau Theory), at the following international conferences:

2nd International Congress of Complex Systems in Sport & 10th European Workshop of Ecological Psychology, Madeira, November 2008

Mozart and Science, Vienna, November 2008

International Conference on Perception in Action, Minneapolis, July 2009

International Workshop on Music, Pattern and Mathematics, Herstmonceux Castle,
East Sussex, August 2010

If the grant awarded funded a PhD studentship, has the student obtained their PhD? If not please give details of current status.

The thesis is being written.

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