I’m Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children During MRI and fMRI

by

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

In partial fulfilment of the requirements of the degree of

MASTER OF ARTS

Individual Interdisciplinary Studies

Department of Psychology

University of Manitoba

Winnipeg

Acknowledgements

The author wishes to acknowledge the willing participants and their parents; Kris Malisza for giving me direction and lighting the way; Brian Haury, Johnathan Hatton, Patricia Gervai, Ernie Packulac, Lindsay McCombe, and Christa Hole for technical support; my proof readers Clove Haviva, Peter Hatton and Anna Lauder; my family for moral support; Toby Martin for going well above and beyond the call of duty; and especially my advisors, C.T. Yu, Nancy Hansen, and Mary Caruso-Anderson, for sharing their vast wisdoms, insights, and guidance.

Dedications

To Peter for his perpetual inspiration, love, and support.

To my committee members, Dr. C.T. Yu, Dr. N. Hansen, Dr. T. Martin, Dr. M. Caruso-Anderson, and Dr. D. Hrycaiko, for continued inspiration, and for unreservedly enduring with me through the thick of it all.

Abstract

Usable Magnetic Resonance Imaging (MRI) and Functional Magnetic Resonance Imaging (fMRI), require motionless patients. Practices have seen children, elderly patients, and those with intellectual disabilities, receiving sedation/anesthesia routinely, chancing a low risk of disabilities. Patients must be alert for fMRI making sedation not an option; however these groups are often unable to meet stillness requirements and must be deprived of this procedure which can indicate potential lifesaving treatments. Behavioural training, particularly shaping or gradually introducing a change in behaviour, has been shown to be effective in preparing both typically developed adults and children in overcoming difficult environments such as MRI/fMRI, although very few studies have been done. This study presented six typically developing children between the ages of five to eight with familiarization (baseline) in a mock scanner after which behavioural intervention ensued, in a non-concurrent multiple baseline design. The behavioural intervention included reinforcement for the contingency of lying motionless, and response cost (the removal of desirable stimuli) as a punishment contingency for movement. During baseline, all children showed a fair amount of head motion in the mock scanner. During intervention, small to large reductions in head motion were observed for five of the six participants. Therefore, use of the mock scanner and the reinforcement/punishment contingencies, may be an aid used prior to actual MRI/fMRI scans for children between the ages of five to eight**:** it is cost effective, may require only a session or two of intervention to be effective, and the potentially dangerous side effects

and/or disabilities of sedation/anaesthesia can be avoided. Limitations and future research are discussed.

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Introduction

Interest in Magnetic Resonance Imaging (MRI) technology has been around since Sir Frederick William Herschel proved through his experiments with heated prisms, and their resultant colours, that there were differing refracted rays of light with radiant heat affecting atoms, over 200 years ago (Boesch, 2004; Eureka, 2011; Herschel, 1800). In 1944, Isidor Isaac Rabi won the Nobel Prize in physics for his work in measuring the nuclear magnetic properties of atoms. By combining radio waves with a magnetic field Rabi could flip the nuclei of atoms and the concept of magnetic resonance was born (Boesch, 2004; Eureka, 2011; Hendee & Morgan, 1984; Rabi, Zacharias, Millman, & Kusch, 1938; Watson, 2011). For their unconnected work in the 1970's in developing Magnetic Resonance Imaging, Paul Lauterbur and Peter Mansfield were jointly awarded the Nobel Prize in Physiology or Medicine in 2003 (Boesch, 2004; Hendee & Morgan, 1984; Watson, 2011). Their work created the needed technology for Raymond Damadian and the FONAR Corporation to be able to manufacture the first commercial MRI scanner in 1980 (Boesch, 2004; FONAR, 2006; Watson, 2011).

Concepts for the functional magnetic resonance imaging (fMRI) began in the 1930's. Not to be outdone by Rabi, Lauterbur and Mansfield, Linus Pauling was awarded two separate Nobel Prizes; the first was for chemistry in 1954 for his work on how blood flow is affected by the magnetic resonance process (Pauling & Wheland, 1933; Profiles in Science, n.d.; Watson, 2011). The notoriety he was afforded, allowed

him to promote the end of nuclear weapons testing winning him the second Nobel Prize, this time for peace in 1962 (Profiles in Science, n.d.; Watson, 2011). Still, it was not until 1990 when Seiji Ogawa further detailed the blood flow changes during the MRI process that the birth of functional magnetic resonance imaging (fMRI) was initiated (Ogawa, Lee, Kay, & Tank, 1990; Watson, 2011).

MRI

MRI has the ability to take images of fine slices of the brain and other bodily organs by emitting a combination of radio waves and a strong magnetic field (Hendee & Morgan, 1984; Watson, 2011). In other words, an MRI provides information on the fixed structure of soft tissues, organs, bones and internal body structures much like a photograph.

Three teslas, the standard strength of a research scanner, are about 50,000 times stronger than the earth's sun (FMRIB Centre, 2011). The MRI causes neurons to take on a different rotation than they would have had otherwise by emitting waves in a pulsing action. These differences can then be captured in an imaged form. MRI provides information on the structure of soft tissues, organs, bones and internal body structures in general (Malisza, 2007; Slifer, Koontz, & Cataldo, 2002; RadiologyInfo.org., April 26, 2011; RadiologyInfo.org., April 27, 2011), such as: tumors of the chest, abdomen, pelvis or brain; developmental anomalies of the brain; aneurysms; disorders of the eyes and inner ears; strokes, pituitary gland conditions; multiple sclerosis; headaches; dementia; heart disorders; blockages and/or enlargements of blood vessels; conditions of the liver, bile ducts, gallbladder, pancreatic ducts, small intestine, colon and rectum; cysts and

tumors in the kidneys and reproductive organs; fibroids; endometriosis and adenomyosis; breast cancer; breast implants; and congenital abnormalities of infertility in women.

fMRI

An fMRI differs from an MRI in that it is a working assessment of neuronal activations (Haller & Bartsch, 2009). Patients may be asked to perform various tasks during the imaging process such as by viewing images and reporting what they see. In other words, an fMRI provides information on the functioning brain of the person while performing these tasks.

fMRI scans have traditionally been used for research purposes in brain mapping (Belliveau et al., 1991; Rubia et al., 1999; Yerys et al., 2009; Yuan et al., 2009) and this is still a vital endeavor as the more we can understand the locations of functions of the brain the more we can develop and then provide efficient treatments. During the fMRI process, neural activity can be seen as the blood flow in the brain increases in the areas being activated. Ogawa introduced the concept of blood oxygenation level-dependent (BOLD) contrast, reflecting the change in the levels of oxygen in the blood during certain activities and/or behaviours (anesthetics, hypoglycemia, inhaled gas mixtures, and MRI). Creating a system to reveal people being deceptive and/or lying (Kozel et al., 2005; Stix, 2008), the source and extent of addictions, seizures and strokes, and brain mapping to distinguish various neurological disorders are also recent objectives of fMRI proponents (Belliveau et al., 1991; Ogawa et al., 1990; Rubia et al., 1999; Watson, 2011; Yerys et al., 2009; Yuan et al., 2009).

In addition, fMRI can be used for actual diagnoses for Alzheimer's disease (Watson, 2011), and much more ground breaking research is being done to identify other brain abnormalities. Blood reacts differently under the MRI's radio waves and magnetic field than it does at other times. This is related to being able to view BOLD contrast in real time while performing tasks given during a MRI (Belliveau et al., 1991; FMRIB Centre, 2011; Ogawa, Lee, Kay, & Tank, 1990; Watson, 2011). As such, the patient must be awake and able to complete, or at least attempt, the task at hand while remaining sufficiently still for the scans to be clear enough to read (Watson, 2011). During an fMRI a wide variety of stimuli; series of shapes and/or colours; and actual pictures in black and white and/or colour, may be presented. Each series of stimuli requires its own associated appropriate responses (P. Gervai, personal communication, June 17, 2011).

MRI/fMRI Scanner

The actual MRI/fMRI scanner is a large, and for many people, a somewhat foreboding looking apparatus with the mass of a mid-size car (see Figure 1). Outside of the machine, the patient is required to lie on a bed that has been mechanically lowered, complete with electronic whirring sounds. After the patient is situated on the bed it is raised, spewing out more rattle, and a head coil somewhat resembling a knight's helmet, is snapped into place around the patient's head (see Figure 2). A series of mirrors connected to the top of the coil are adjusted so that the patient, while laying on his/her back looking up into them, can see the control room located in the direction of his/her feet. The bed then slides into the scanner's main bore which is a large tube. Once within the bore, lights are seen and knocking noises and buzzes are heard. The overwhelmed

patient is then asked to remain still for an extended period of time. The experience can be daunting for anyone, but has understandably been proven to be an especially unnerving circumstance for children. Consequently, young children are routinely prepared for MRI with sedation (Lubisch, Roskos, & Sattler, 2008; Malisza, Martin, Shiloff, & Yu, 2010; Malviya et al., 2000).

Since an fMRI requires the patient not only be awake and alert, but often be involved with a visual-motor task while being imaged, sedation is not an option. A hand held response pad is regularly employed so the patient can react to stimuli projected before them by pressing buttons on the pad. The required finger movement can have a domino effect creating movement throughout the entire body, although the patient may be unaware of their motion (Epstein et al., 2007; Yang, Ross, Zhang, Stein, & Yang, 2005).

During the fMRI scanning procedure, the patient is required to remain as still as is possible to ensure efficiency in taking the scans. Movement can cause blurring of the scanned picture, requiring them to be retaken and therefore extend the amount of time the patient is required to spend inside the scanning tube. The procedure is the same as for an MRI.

MRI/fMRI Advantages

Both MRI and fMRI scans are safe, non-invasive Interventions, unlike the harmful radiation emitted during X-rays, Computed Tomography (CT), Positron Emission Tomography (PET), and Single Photon Emission Computer Tomography (SPECT); the latter two also require the use of contrast agents to be administered, usually

by mouth but sometimes by needle insertion for intravenous distribution, to disperse chemicals throughout the body (de Amorim e Silva, Mackenzie, Hallowell, Stewart & Ditchfield, 2006; Woods-Frohlich, Martin, & Malisza, 2010). MRI/fMRI provides clear pictures with an extremely high resolution, equal to or better than those of its predecessors (Hendee & Morgan, 1984; Watson, 2011). So much so, that clinical applications are now relevant in diagnosing specific central neurological disabilities such as headaches, cluster headaches, Parkinson's disease, stroke, amyotrophic lateral sclerosis (ALS) and multiple sclerosis (Lenzi, Raz, & Pantano, 2008;Weiller, May, Sach, Buhmann, & Rijntjes, 2006).

In addition to lending itself to diagnoses, fMRI offers: surgery guidance in identifying areas of concern for epilepsy in the brain by being able to observe patterns of functional reorganization, and in epilepsy surgery decision-making by reviewing functionally active cortex patterns to determine if surgery is the best option. In so doing, epilepsy surgeries can be more accurately directed or avoided completely (Liégeois, Cross, Gadian, & Connelly, 2006). In children, specific abnormalities such as epilepsy (Epilepsy Diagnosis, 2011), fetal alcohol syndrome (Wozniak, 2006), attention deficit hyperactivity disorder (ADHD) (Rubia et al., 1999; Sprung et al., 2012), autism spectrum disorders (Ostrow, 2010; Seyffert & Silva, 2005), dyslexia, and various types of intellectual disabilities such as Joubert Syndrome, Williams Syndrome, Velocradiofacial Syndrome, and Fragile X (Seyffert & Silva, 2005) are being identified.

Sedation. Increasingly children are being referred for MRI and fMRI scans. Children under the age of 6 to 8 years-of-age often receive routine procedural sedation

(de Amorim e Silva et al., 2006; Slifer et al., 2002) due to their lack of understanding of the process, their inability to subdue their anxieties, thereby inciting movement behaviours (de Amorim e Silva et al., ; Lubisch et al., 2008).

Unfortunately, sedation comes with a myriad of possible side effects, including: nausea, vomiting, rashes, paradoxical reactions (the opposite effect than which is expected such as excitement and agitation), spasms of the laryngeal cords causing a partial blocking making it difficult to breathe in, and inadvertent drug overdoses. Respiratory concerns are likewise an issue, such as: upper airway obstruction, pulmonary aspiration, respiratory arrest, hypoxaemia (decreased pressure of oxygen in the blood) and apnea (cessation of breathing). Sedation complications can also include not being given an adequate amount of sedative medication, so that the patient wakes up part-way through the procedure, and allergic reactions (Jenkins & Baker, 2003). Sedation during fMRI has elicited seizure behaviours (Allen, 2004; Kannikeswaran, Mahajan, Sethuraman, Groebe, & Chen, 2009). Bradycardia (significant decreases in heart rate), decreases in systolic blood pressure, body temperature, prolonged sedation, disquieting behaviours and/or agitation (Alp, Orbak, Güler, & Altinkaynak, 2002; Tith, Lalwani, & Fu, 2012), aspiration, hypotension, and apnea (Tith et al., 2012) were also noted. Blood oxygen desaturation (Alp et al., 2002; Sury, Harker, & Thomas, 2005), as well as respiratory obstruction (Cortellazzi et al., 2007; Tith et al., 2012), psychomotor agitation, ataxia (lack of muscle control), sweating, dizziness (Cortellazzi et al., 2007) mild to severe hypoxia (inadequate oxygen in cell tissue), vomiting and nausea, hiccupping, and diarrhoea (Alp et al., 2002; Cortellazzi et al., 2007; Kannikeswaran et al., 2009; Tith et

al., 2012), and paradoxical reactions (behaviours opposite of the expectations) (Kannikeswaran et al., 2009) have been reported. Delayed adverse behaviours (one hour or more after the sedation and MRI) have included hyperactivity, ataxia, vomiting, nausea, sweating, dizziness (Cortellazzi et al., 2007), coughing and excessive secretions (Tith et al., 2012). Often medical intervention is required (Allen, 2004; Tith et al., 2012), including intubation and unplanned hospital admittance (Tith et al., 2012). The failed scan must then be rescheduled or attempted using a general anaesthesia (Lubisch et al., 2008; Malviya, Voepel-Lewis, & Tait, 1997; Malviya et al., 2000).

General anaesthesia. General anaesthesia can have devastating side effects causing permanent physical disabilities such as congestive heart failure, postoperative cognitive dysfunction (POCD), blurred vision or blindness, hearing loss or deafness, nerve injuries, and mouth/dental damage (Jenkins & Baker, 2003). In addition, permanent learning disabilities (LD) including attention deficit hyperactivity disorder (ADHD) (Sprung et al., 2012), other LDs encompassing reading, writing, language and math disabilities (Wilder et al., 2009) may be resultant. The quintessential side effect is that of mortality (Jenkins & Baker, 2003). General anesthesia during MRI has elicited hypotension (Odegard et al., 2004; Slovis, 2011), bradycardia (Sandner-Kiesling et al., 2002; Slovis, 2011), headache, fatigue, vertigo, fever, seizures, and agitation (Sandner-Kiesling et al., 2002). Slovis (2011) has also noted hallucinations, hypertension, increased bodily secretions, respiratory distress, and myocardial depression (low heart rate). Behavioural reaction has been severe enough to have necessitated medical intervention such as laryngospasms requiring tracheal intubation (Sandner-Kiesling et al.,

2002), and admittance to a cardiac intensive care unit due to cyanosis (bluish skin colour due to inadequate oxygen in the blood) and low cardiac output (Odegard et al., 2004). Delayed adverse behaviours have included vomiting and nausea, hiccupping, diarrhoea, and infections/allergies such as conjunctival reactions (eye related), rashes, bronchospasms, rhinitis (nose related), and laryngitis (throat related) (Sandner-Kiesling et al., 2002).

General anaesthesia may be administered several ways, including: inhalation through a mask, intravenous injection, orally, or rectally. These methods may require a tube down the throat and/or a ventilator. Airway complications comprise of hypoxaemia, and pulmonary aspiration (going down the wrong pipe). Cardiovascular complications include hypotension, arrhythmia, and cardiac arrest. Another complication can be oxygen desaturation which would then require auxiliary oxygen, repositioning of the airway, or both. General anaesthesia may not be possible if the patient suffers a complicating factor as sleep apnea, a narrow airway or multiple allergies (Lubisch et al., 2008; Malviya et al., 2000).

Complications of either sedation or general anaesthesia may result in extended care, including hospital admissions, rescheduled appointments, financial and time costs to patients and families, travel time, repeated trips to hospital, and lost work time. Financial considerations must also be appreciated as procedural costs can run from $400-$3,500 (Compare MRI Cost, 2010). Notably, a delayed and/or rescheduled scan, or the inability to perform a scan due to one of the complicating factors of anaesthesia listed above, may result in a much needed diagnosis being delayed (Lubisch et al., 2008; Malviya et al.,

1997; Malviya et al., 2000). Of particular concern is that sedation or general anaesthesia can directly cause permanent disabilities, or death (Jenkins & Baker, 2003).

Physical restraints have been used as a measure to avoid sedation and/or general anaesthesia (Yang et al., 2005). However, paraphernalia such as bite bars and compression pads can actually increase anxiety and fidgeting.

MRI/fMRI Disadvantages

Due to the strength of the magnetic field used, any type of metal is prohibited within the scanner, and often even in the MRI/fMRI room itself. Even experimenters and technicians cannot wear any metals, including: jewellery (watches, earrings, necklaces, and non-removable piercings), clothes with zippers, barrettes and bobby pins, and coins, pens, and credit cards (with a metal/magnetic strip) in pockets. This rules out prospective patients who may have pacemakers, artificial heart valves, cochlear implants, intrauterine devices (IUDs), metal pins, screws, or plates (Watson, 2011). Dental work involving permanent implants can likewise eliminate possible candidates (metal bridges, crowns and non-removable braces). Many tattoos are also problematic because of the iron oxide used in the inks.

Claustrophobia, or the fear of enclosed spaces, can limit or negate time in the scanner. Being inside the bore can give someone with claustrophobia a feeling of being trapped, but with the aid of behaviour training, this too may be overcome.

Clear images can only be taken when the patient is able to remain motionless (Epstein et al., 2007; Watson, 2011). Any head movement will cause a blurring of the scan rendering it useless. This becomes especially challenging when dealing with certain

populations, such as: young children, people diagnosed with intellectual disabilities, and people diagnosed or suspected of having Alzheimer's disease (Watson, 2011).

MRI/fMRI scanners are expensive and are therefore only available for use in major hospitals and research facilities. This means waiting time for a scan can be lengthy and may involve travel for those who live outside of a metropolitan area.

Previous Research on Reducing Motion During MRI/fMRI

Studies utilizing a mock scanner. A mock scanner is typically constructed using discarded or outdated MRI/fMRI materials such as an MRI/fMRI bore and bed. Recorded sounds and lights inserted inside the bore simulate those of an authentic scanner. One advantage of using a mock scanner in place of an actual MRI/fMRI, is that it is less expensive to use than conducting training in the real scanner (Compare MRI Cost, 2010). It also does not interrupt necessary clinical scanning schedules and thus does not interfere with medical procedures. As a final point, when using a mock scanner the waiting time to receive training is nil.

In 1993, Slifer, Cataldo, Cataldo, Llorent, and Gerson used potentiometers connected to the foreheads of 4 "normal" children between the ages of 5 and 6 years old (2 boys and 2 girls) to measure the amount of their head movement in an MRI/fMRI mock scanner. Three conditions were presented during simulated scanning using an inactive MRI/fMRI scanner: 1) no entertainment or feedback; 2) a non-contingent cartoon was played with no feedback; and 3) a cartoon was played contingent on lack of movement. If movement occurred during the 3rd condition the cartoon ceased for 3 seconds, and non-movement received feedback with reinforced praise, tokens and

edibles. At the end of the first and second conditions, a non-contingent reward (toy) was presented. After the third condition a toy could be purchased by handing in tokens earned during scanning. Slifer et al.'s results indicated condition 1 did not result in movement reductions acceptable for an MRI, movement actually increased in condition 2 for 50% of the children, and in condition 3 all children responded with motion decline as the experimenters deemed as acceptable for an MRI, although no actual MRI was given. Therefore, they concluded that it is feasible to use operant conditioning to teach children to tolerate an MRI scan without sedation. However, Slifer used the same children for all 3 conditions, making practice effects an issue.

In 2002, Slifer et al., again worked with children in a mock scanner setting. Of the four children aged 4 to 7 in this study, the two girls were typically developing, while the two boys had been diagnosed with ADHD. Potentiometers were used as they were in the previous study with the addition of a videotape which displayed pictures of familiar objects in a random series and a hand held response pad (Don Johnston Inc., Volo, IL). The thumb button was to be pressed when a blue square appeared, and the index finger to be pressed when it disappeared. Verbal feedback and a chosen toy were presented after the session. As a result, head movement decreased.

de Amorim e Silva et al., (2006) did a retrospective study with 134 children within the ages of 4 to 16 years-old. Children who otherwise would have required sedation, due to "neurological impairments", motions issues, fear of the procedure and/or needles, and claustrophobia, were referred by their doctors directly to this study. This study found that after only one session in their mock scanner of 30 minutes to an hour

with praise and a non-contingent chosen video to watch, 90% were able to meet criteria which entailed remaining motionless for a period of 5 minutes. Of those who underwent the mock scanner training, 98% went on to have an actual MRI/fMRI with a 90% success rate.

Although Slifer (Slifer et al., 1993; Slifer et al., 2002) did use a mock scanner for training in the two previous studies, and a hand held response pad for the latter, he did not measure whether the training introduced generalized from the mock scanner to the actual MRI/fMRI. de Amorim e Silva et al., (2006) also used a mock scanner for training purposes and although they did have success in generalizing to an actual MRI/fMRI, they did not use a hand held response pad which has been shown to trigger head motion (Epstein et al., 2007).

Studies not utilizing a mock scanner. In 1994, Slifer, Bucholtz and Cataldo, presented 10 children ranging in age from 3 to 7 years of age, all requiring radiation treatment, to behavioural relaxation training. The training, which took place in the actual radiation treatment rooms, was designed to desensitize and familiarize the children with the scanner, thereby decreasing their level of motion. Stickers were awarded to the children upon compliance to each step in a hierarchal list of behaviours (e.g., sit on a chair beside the treatment bed, lie on the bed, and "hold still" for a specified amount of time), which were traded in at the end of the session for a tangible toy. The results showed that 8 of the 10 children were able to tolerate their actual radiation treatment without sedation.

Slifer returned in 1996, with 11 children ranging in age from 2.5 to 7 years of age, requiring radiation treatment. In addition to the previously mentioned relaxation and desensitization training, the children were presented with a non-contingent video for distraction purposes while they were lying on the treatment bed. The training again took place in the radiation treatment rooms. Ultimately, 9 out of the 11 children were able to undergo their radiation treatments without sedation.

In 2005, Yang et al., completed a study using 12 "normal" male adults (mean age of 26.5), completing several tasks within one fMRI session after one training session. Head motion was monitored using a real-time fMRI system developed on standard MR hardware where during scanning tasks, arrows on the periphery of the MRI/fMRI screen would change colour indicating to the participant that their head motion had exceeded acceptable parameters. Head motion was reduced significantly in all participants. Similar studies have not been done with children.

A 2009 study by Yuan et al., analyzed head motion data from 323 children (155 girls and 168 boys), between the ages of 5 and 18 years, taken between the years 2000 and 2005. Four language tasks were completed within one fMRI session using the concept of familiarization to increase sustainability during scanning. Prior to the session the children were familiarized with the apparatus by viewing an 8-minute film, and priming for each of the four tasks. Younger children (no age cut-off was given) were additionally allowed time inside of the scanner to further acquaint themselves with the equipment and forthcoming proceedings. During the scan the children's motion was monitored by means of a closed circuit TV. When motion was deemed excessive, the

scan was stopped and instructions about the importance of remaining still were reiterated. Not surprisingly, their findings revealed motion decreased with age, and girls displayed less motion overall than did boys. If these finding are confirmed, potential implications of positive findings for gender and age could help to identify a subset of the population (younger boys) who would benefit from this intervention as well as groups of children who are less likely to need it (older children and girls). Therefore, Yuan et al., concluded that more rigorous means of minimizing motion in children is necessary.

As has been previously mentioned, behavioural training in the actual MRI/fMRI is expensive (Compare MRI Cost, 2010), and one major way to reduce expense is to use a mock scanner (or a mock radiation therapy set-up for Slifer's former studies). A mock scanner in combination with various behavioural or relaxation procedures, as previously described, has been effective in reducing fear/anxiety by presenting familiarization techniques (de Amorim e Sliva et al., 2006; Slifer et al., 1993; Slifer et al., 2002). Furthermore, a mock scanner is efficient as effective training can be completed within a single session (de Amorim e Sliva et al., 2006).

Purpose and Hypothesis

Behavioural intervention has been shown to be effective in preparing both typically developed adults and children in overcoming difficult environments such as MRI/fMRI (de Amorim e Silva et al., 2006; Yang et al., 2005), although very few studies have been done on this. Although familiarization with the mock scanner can greatly reduce fear and anxiety associated with the actual scanning procedures (de Amorim e

Silva et al., 2006; Malisza et al., 2010), mock scanner exposure alone was not effective in reducing motion (Slifer et al., 1993).

This purpose of this study was to evaluate behavioural techniques presented in a mock scanner to control for motion with typically developing children simulating MRI and fMRI scanning procedures while utilizing a hand held response pad. The behavioural intervention used included reinforcement for the contingency of lying motionless, and response cost (the removal of desired stimuli) as a punishment contingency for movement. The general research plan involved each participant receiving familiarization (baseline) sessions in a mock scanner, followed by the behavioural intervention in a non-concurrent multiple baseline design across participants. I hypothesized that children would show a larger amount of movement during baseline than during behavioral intervention.

Method

Participants and Setting

Six typically developing children aged five to eight years participated in this study; there were four females and two males. Participants were recruited from a previous study conducted at the National Research Council Canada Institute for Biodiagnostics (NRC-IBD) in Winnipeg. Participants were selected randomly from among a pool of previous study participants who indicated a willingness to be contacted for future studies. Initial contact was by telephone using a recruitment script (see Appendix A), and was followed up by a recruitment letter (see Appendix B) accompanied by a project description and consent form (see Appendix C) for those parents who

expressed interest. Approximately a week later the parents were then contacted again by telephone using a follow-up recruitment script (see Appendix D). Even after parental consent (see Appendix E) and participant assent (see Appendix F) were obtained, the assent of the participants was assessed at each contact throughout the study (e.g., by their willingness to work with the researchers). A session was cancelled and rescheduled for another day if a participant declined.

Exclusion criteria would have included children who were left handed, as the only hand held response pad available for the mock scanner was designed for a right hand, and children who did not speak or understand English. Neither of these scenarios applied to the children contacted.

None of the children had physical disabilities other than the need for mild vision correction for one child. Glasses were not worn during sessions to prevent glare from the picture presentation and video recorder, however, this did not affect the ability to view the picture presentation adequately as this child's lens prescription was minor and the child often went without her glasses in her daily life. While children with physical disabilities were not excluded in any way, none had presented themselves during the original study where these participants were drawn.

This study took place in a room, measuring approximately 10 by 30 m, at the St.Amant Research Centre in Winnipeg. The room was equipped with a mock scanner, the pressure pillow system, the hand-held control pad, a camcorder, a desk top computer on a stand beside the mock scanner's bed, a table with a projector and a laptop computer, a room divider with a 3 m high wheeled stand with a top that was a

1.5 by 3 m screen where the picture presentation was projected. A room divider partitioned off an area for the parents and siblings to wait where a couch, two end tables, a table lamp, a child sized table and two chairs, a play mat on the floor, a chest with toys in drawers and books arranged on top, and an adult sized table with three chairs (see Figure 3).

Instruments and Materials

Mock scanner. The mock scanner was constructed at NRC-IBD in Winnipeg by Calvin Bewsky, with funding from the University of Manitoba, as a way to help children overcome their fear of an actual MRI/fMRI (see Figure 1) (National Research Council Canada, 2009). The mock scanner was similar in size and appearance to a working scanner. Lights have been placed in the scanner tube to simulate those within a scanner, and a computer's DVD player provided the appropriate sounds at a volume similar to an actual scanner. Soft earplugs or headphones were provided to reduce the noise. The lights and sounds were both on during sessions to simulate an actual scan. The bed moved inside the tube and the coil (helmet) enclosed the head (see Figure 4). On top of the helmet were mirrors which allowed the child to see the end of the bed while looking straight up (see Figure 2). During the scans, the experimenter was beside the child, and in-between sets (three sets per session), the experimenter spoke with the child regularly.

Mock scanner hand held response pad. In the mock scanner, the hand held response pad was a white hand shaped instrument about 25 cm long. The hand nestled in the curved plastic frame with a Velcro strap around the wrist and another around the middle of the forearm. The fingers and thumb comfortably fell into curved grooves.

There were four black knob-like buttons located on the end of the finger groove (see Figure 5). Buttons could be pressed in accordance to pictures being shown on the screen while the participant was lying inside of the tube. However, the hand control response pad was not connected to collect data as the PowerPoint® program used for the picture presentations did not allow for that function.

Pressure pillow system. A "pillow", created by Dr. Karl Edler, was the method used to determine the amount of head motion during mock scanner sessions. The pillow was designed with an array of tubes pressure sensitive to head motion left to right (ear to ear), head up and down (chin up and chin down), and general head pressure (the amount the head is pressing on the pillow) while the head is resting on the pillow (see Figure 6). The pillow was used to record head motion during all sessions throughout the study. Left-right (ear to ear) and up-down (chin up and chin down) motion movements were the dependent variables in this study (described later). Head pressure on the pillow was not analyzed as it showed relatively smaller variability than left-right (ear to ear) and up-down (chin up and chin down) motions during both baseline and intervention phases.

Filming. A camcorder was mounted on the coil to record any head motion. A white 0.5 cm square of duct tape was placed in the centre of the child's forehead to enhance ease of tracking movement. Dark sheets were place on the bed to provide contrast for the white dot. This allowed later review of the film to confirm the pillow's assessment of movement.

Pictures. Three separate sets of still pictures were presented during each session. The first set included 19 pictures from popular cartoons in a set lasting approximately one

minute long; followed by 43 pictures of baby animals, the set lasting approximately two minutes long; and ending with a set of 81 pictures of smiling people's faces, the set lasting approximately four minutes long, all in a PowerPoint® program. All pictures were chosen to be friendly, appealing, and non-threatening. After each set of pictures there was a one-minute break before the next set of pictures began, making each baseline session last approximately 10 minutes. The elves were designed to appear human-like but with a cartoon aspect to be appealing to children. The colours of green and red were chosen as they are complimentary (opposite) colours to each other and the stance of the green elf was standing, while the red elf was waving and had one knee bent and raised (see Figure 7). These differences were intentional to make it easy for the children to distinguish between the two pictures. In the set of pictures with smiling people's faces, to sustain continuity, only the faces of the elves were shown. Since there are many interpretations of what an elf looks like, the children were shown the pictures of elves used in this study in advance so they were familiar with the pictures they were looking for as well as the difference in colours.

Colour test. The red and green complimentary colours of the elf pictures would have only been effective if the children were not red-green colour blind. In order to rule out the possibility of red-green colourblindness, during the first visit, before the first session began, the children were shown the pictures of elves and the experimenter asked the child what colour the elves were in the pictures. When they answered correctly, the session proceeded. All children identified the colours correctly. Had any of the children not been able to correctly answer the colour questions, elves of different colours or in

shades of blacks, greys, and whites would have been used in order to accommodate their possible red/green colour blindness.

Non-concurrent Multiple Baseline Design Across Participants

This study used a non-concurrent multiple baseline across-individuals design; which is AB designs of different individuals at different times (Christ, 2007; Kazdin & Kopel, 1975; Novotny et al., 2014; Watson & Workman, 1981). This design compensates for history issues; referring to event(s) that could affect the dependent variable for a participant by introducing a change in routine (Christ, 2007). It is unlikely all participants would have experienced the same issues at various times. It also allowed time staggered starting dates applied to accommodate scheduling issues. Previously determined randomized numbers of baseline sessions of two, three, or four were used. Participants 1 and 5 (P1 and P5) each received four baseline sessions; P2 and P4, three baseline sessions; and P3 and P6, two baseline sessions. Those participants receiving two and three baseline sessions completed their baseline during a single visit, while those requiring four baseline sessions were completed over two visits with two baseline sessions per visit. Following baseline sessions, all participants received four treatment sessions, over two visits of two sessions each.

Variables and Procedures

Dependent variable. The dependent variable was head motion measured in the mock scanner by the pressure pillow. The pillow was connected by a series of tubes to a computer which recorded the data, with values ranging from +1 to –1 for each of the three directions: left/right (ear to ear), chin up/chin down, and general pressure. After a

child had settled into the mock scanner and was resting comfortably on the pillow, the experimenter initialized the readings to zero. The computer software displayed a ball on the computer screen (visible only to the experimenter) that moved left/right, up/down, or larger/smaller (general pressure) dependent on the direction of the pressure exerted upon it. The pressure pillow readings in all three directions were recorded by the software program approximately seven times per second.

Baseline procedure. Before each session began, a white 0.5 cm square of duct tape was placed in the middle of the forehead of the child. The participant was made comfortable on the scanning bed with the pressure pillow (Figure 6) under their head, and the hand control response pad was placed on their dominant right hand. The children were then asked to react to stimuli within the picture presentation: "Try to stay as still as you can. Press the button with this finger (touch first finger on the right hand in the hand held control pad) when you see the red elf, and press this button with this finger (touch second finger on the right hand in the hand held control pad) when you see the green elf." The children were then asked to repeat the instructions back to the experimenter, and they were told the experimenter could not talk to them while they were in the scanner. The children were then asked if they were ok, and if they were ready to start. Once the child responded positively, the bed was pushed into the bore; "Whee". The three separate sets of still pictures (cartoons, baby animals, and smiling faces) were presented during each session with a 1-minute break between each set. Each set also included pictures of the red elf and green elf, randomly presented four times each during the 1-minute cartoons set, six times each for the 2-minute animals, and 12 each for the 4-minute smiling faces set.

Using the PowerPoint® program, each picture was presented for one-quarter of a second (250 milliseconds), with two seconds in between each picture to allow time for responding as was typically done during actual MRI/fMRI. Participants were asked to perform the two finger red elf/green elf response task as the picture presentation continued throughout the session regardless of head movement during all baseline sessions. The experimenter did not communicate with the participant while the pictures were being presented. Verbal praise such as, "good job!", "I can tell you are working hard to stay still", and "you are really good at this research stuff", were given incontinently during the break between sets of pictures. At the completion of each session (i.e., all three sets of pictures have been presented), the child received a choice of a take home toy (approximately $1-$3 in value) and a choice of edible (chocolate bars, gummy bears, trail mix) regardless of their performance.

When the child displayed significant discomfort at any time by crying, calling for their parents, rapid breathing, or unwillingness to continue, the session ended and was either rescheduled or cancelled, dependent on the child's and parent's wishes. The children were asked at the beginning of each set, "Are you ok? Are you ready to start?" When the children did not answer positively, any issues were immediately dealt with, and throughout the study sessions were paused in order to insure the child's comfort. One of the issues this comprised of was readjusting the earplugs for the earlier participants. A more pliable brand of earplugs were obtained for use with the later participants' sessions. Realignment of the pillows both for comfort and for maximum data output was also a concern particularly with the older children as they had larger heads; the younger

children's smaller heads nestled into the centre of the pillow system so that this was not a concern for them. The dark sheets needed to be readjusted throughout the study to maximize comfort and colour contrast for the white dot on the participants' foreheads.

Behavioural intervention procedure. During the behavioural intervention phase, the sessions were conducted using the same procedures as described for baseline sessions except for one difference. Employing a response cost technique (the removal of desirable stimuli) as a punishment contingency for movement, the picture presentation ceased playing for 5 seconds when excessive motion was noted, after which the picture presentation continued to play again.

Computer display and measurement. The pressure pillow conveyed information through pressure sensitive tubes to a connected computer. This display resembled a bull's-eye with a ball inside. When the child initially lay on the pressure pillow, the ball was centred on the screen so it rested in the centre circle of the bull's-eye (see Figure 8). Through the experimenter's observation it was noted when the ball left the centre circle, movement appeared to be more than the 2 mm required for a successful clinical scan. As the child's head moved left-right (ear to ear) and/or up-down (chin up and chin down) the ball within the bull's-eye moved representatively (see Figure 8). It was when the ball travelled outside of the bull's eye's inner most circle that the picture presentation was halted for 5 seconds.

A maximum value of +1 was assigned by the computer program indicating the maximum movement in one direction (e.g., either chin up on the y-axis, or head to the right on the x-axis). Likewise, a maximum value of -1 indicated the maximum

movement in the other direction (e.g., either chin down on the y-axis, or head to the left on the x-axis). A value of zero indicated no movement in the chin up-down and head left-right directions.

Reliability

All sessions were conducted by the same experimenter. Procedural integrity checks were conducted for each participant during at least 33% of the familiarization/baseline and behavioural intervention sessions. The observer evaluated the experimenter using a checklist of steps to be followed on a session (see Appendix G). A session was scored as correct when all steps were carried out correctly. The percentage of sessions delivered correctly was 100%.

Results

Scatter plots

Figure 9 shows scatter plots of head motion for P1 (top row) through P3 (bottom row) during baseline (left graph) and early and late intervention periods (middle and right graphs, respectively). All baseline data for each participant, indicated by *n* data points, and the first and last *n* data points during intervention are shown in each graph for each participant. For example, each graph for P1 contained 7142 data points. The vertical axis (*y*-axis) represents head up and down (chin up and chin down) head motion, and the horizontal axis (*x*-axis), left to right (ear to ear), head motion as measured by the pillow system, in values ranging from -1 to +1. Thus, the scatter plots show how movements are distributed within a three-dimensional space around the head. The number of data points differed during baseline for those who had the same number of baseline sessions as the

duration of some sessions was shorter when the picture presentation ended prematurely (see Discussion section). The number of data points differed for participants for intervention although all received four sessions as it encompassed not only the duration of the sets but also the intervention time as each time the child moved the picture presentation ceased for 5-seconds. For P1, head motion during baseline tended to concentrate in three relatively large regions: top left quadrant, centre with substantial left-right motion (ear to ear), and lower left quadrant. During the early period of the intervention phase, motion in the top and lower left quadrants decreased substantially and it was confined mainly to the centre region with slight increases in upward motion in the centre and the top right quadrant. During the late period of the intervention phase, the upward motion observed during early intervention subsided and motion was confined generally to a relatively small region. For P2 (5006 data points per graph), head motion during baseline tended to concentrate in two regions: a large region in the centre lower area, and a smaller area it the upper left quadrant. There was also scattered motion detected on the upper and lower right quadrants detecting both sporadic chin up and chin down movements. During the early period of the intervention phase, scattered motion decreased substantially and motion was mostly confined to a single area in the central upper quadrants. During the late period of the intervention phase, motion was concentrated in three small areas (a small area in the middle of the top left quadrant, near the centre, and a small area in the bottom right quadrant), with scattered movements in the bottom left and top right quadrants. P3's (7744 data points per graph) baseline head motion tended to concentrate in three relatively large regions: top right quadrant, right

centre with substantial left-right (ear to ear) motion, and the central lower left quadrant. During the early period of the intervention phase, motion in the top and lower left quadrants decreased substantially and it was confined mainly to the upper right quadrant. During the late period of the intervention phase, the upward motion observed during early intervention subsided and motion was confined generally to one region near the centre.

Figure 10 shows scatter plots of head motion for P4 (top row) through P6 (bottom row) during baseline (left graph) and early and late intervention periods (middle and right graphs, respectively). As with Figure 9, all baseline data for each participant are indicated by *n* data points, and the first and last *n* data points during intervention are shown in each graph for each participant. The vertical axis (*y*-axis) represents up and down (chin up/chin down) head motion and the (*x*-axis), left and right head (ear to ear) motion as measured by the pillow system, in values ranging from -1 to +1. For P4 (7358 data points per graph), head motion during baseline was noted in all quadrants with dominate concentrations along the upper *y*-axis indicating upward head movement, and along the right *x*-axis indicating right head movement. In the upper right quadrant, scattered motion detected less motion in both upward and right movements. During the early period of the intervention phase, motion was confined mainly in the upper right region indicating upward right motion. During the late period of the intervention phase, there was a substantial reduction in motion in the top right quadrant, but motion was concentrated along the *y*-axis and towards the right just above and below the *x*-axis. P5's (10850 data points per graph) head motion during baseline occurred primarily in three relatively large regions: top right quadrant, and lower left and right quadrants. During the

early period of the intervention phase, motion remained high and shifted slightly upwards, and to the upper and lower right quadrants. During the late period of the intervention phase, there was very little change except for a small reduction in the upper right corner of the upper right quadrant. For P6 (4462 data points per graph), head motion during baseline tended to concentrate in two relatively large regions: top right quadrant, and in the centre. During the early period of the intervention phase, motion in the top right quadrant decreased substantially and it was confined mainly to the centre and lower right regions. During the late period of the intervention phase, the motion observed during early intervention subsided further and was confined to a very small region near the centre.

Line graphs

Figure 11 shows the extent of horizontal and vertical head motions for P1 and P2 across all sessions during baseline and intervention phases. Each line graph shows the pressure values (between –1 and +1) as a result of head movement from the centre set, as measured by the pressure pillow system. During baseline, P1's horizontal head motion (top graph) was mostly towards the left (negative values), whereas vertical head motion (second graph from the top) occurred in both chin up and chin down directions (see Figure 9 top left graph for a scatter plot of the same baseline data). During the intervention phase, P1's horizontal and vertical head motions were reduced substantially during approximately the first and last one-third periods of the phase. During the middle third of the intervention phase, P1's horizontal and vertical head motions returned to approximately baseline levels, although the left-right (ear to ear) motion was more evenly

distributed compared to baseline. The reduction in motion during the early and latter parts of the intervention phase can also be seen in his scatter plots in Figure 9 (top row, middle and right graphs). During baseline, P2's horizontal head motion (second graph from the bottom) was mostly towards the right (positive values), whereas vertical head motion (bottom graph) occurred first in the chin down direction switching halfway through to chin up directions (see Figure 9, middle row, left graph for a scatter plot of the same baseline data). During the intervention phase, P2's horizontal and vertical head motions ceased during approximately the final quarter period of the phase. Horizontal and vertical motions during the first three quarters of the intervention phase were similar to baseline levels. The reduction in motion during the latter part of the intervention phase can also been seen in her scatter plot in Figure 9 (middle row, right graph).

Figure 11 shows the horizontal and vertical head motions for P3 and P4 across all sessions during baseline and intervention phases. During baseline, P3's horizontal head motion (top graph) was mostly towards the right (positive values), and vertical head motion (second graph from the top) was mostly chin upward (see Figure 9 bottom left graph for a scatter plot of the same baseline data). During the intervention phase, P3's horizontal and vertical head motions were reduced substantially during approximately the early to middle period of the intervention phase. However, her horizontal and vertical head motions returned to near baseline levels towards the end of the intervention phase. The change in motion during the intervention phase can also been seen in her scatter plots in Figure 9 (bottom row, middle and right graphs). During baseline, P4's horizontal head motion (second graph from the bottom) was towards the right (positive values), and her

vertical head motion (bottom graph) favoured chin upward motion (see Figure 10 top left graph for a scatter plot of the same baseline data). P4's horizontal and vertical motions appeared to show no reduction throughout the intervention phase, even though the regions have shifted as shown in Figure 10 (top row, middle and right graphs).

Figure 13 shows the horizontal and vertical head motions for P5 and P6 across all sessions during baseline and intervention phases. During baseline, P5's horizontal head motion (top graph) was predominantly towards the right (positive values), and vertical head motion (second graph from the top) were predominantly chin downward (see Figure 10 middle row, left graph for a scatter plot of the same baseline data). During the intervention phase, P5's horizontal and vertical head motions were similar to baseline levels, although there was more chin upward motion compared to baseline. The lack of change during intervention can also be seen in her scatter plots in Figure 10 (centre row, middle and right graphs). During baseline, P6's horizontal head motion (second graph from the bottom) tended to occur towards the right (positive values), and vertical head motion (bottom graph) initially occurred in a chin upward direction (positive values) and then changed to a chin downward direction (negative values) (see Figure 10 bottom left graph for a scatter plot of the same baseline data). During the intervention phase, P6's head motions were reduced substantially during most of the intervention phase. During the intervention phase, P6's vertical head motions remained similar to baseline for the first half of this phase, after which during the second half the vertical movements were greatly reduced. The change in motion during intervention can also been seen in his scatter plots in Figure 10 (bottom row, middle and right graphs).

Summary

During intervention, the largest reduction in regions of head movement was shown with P6 (Figure 10) along with a clear reduction in the extent of head movement (Figure 13). There was a reduction in regions of head movement for P1 and P3 (Figure 9) and this was accompanied by a modest reduction in movement (Figures 11 and 12).

During intervention, P2 and P4 also showed a change in regions of head movement during intervention (Figures 9 and 10), but neither participant showed clear movement reduction, except towards the end of intervention for P2 (Figures 9 and 11). P5 showed no noticeable changes in regions of head movement (Figure 10) and in movement reduction (Figure 13).

Discussion

The purpose of this study was to examine if behavioural intervention could reduce head motion in a mock MRI scanner using a finger response pad. The general research plan involved each participant receiving familiarization/baseline sessions in a mock scanner, followed by behavioural intervention also in a mock scanner. It was hypothesized that children would show a lower amount of movement after the introduction of behavioral intervention relative to baseline. While there was not a large experimental effect for all participants, the contingency applied had a large effect for P6, a small to moderate effect for P1 through P3, and a partial effect for P4 thereby providing some support for my hypothesis.

These results are consistent with aforementioned studies using mock scanners. As with the previous studies by Slifer et al., (1993); Slifer et al., (2002); and de Amorim e

Silva et al., (2006), this study found head motion in the mock scanner was reduced during the behavioural intervention.

Additionally, this study extends this past research as Slifer et al., (1993) used the same four children for three conditions, making practice effects an issue, while this present study used six children across two conditions thereby reducing practice effect possibilities. Slifer et al., in 2002 did not address movement as an immediate contingency and only provided feedback after the session had ended, while this study ceased to play the picture presentation as movement increased in real time. de Amorim e Silva et al., (2006) did not use a hand held response pad which has been shown to trigger head motion; and the Yang et al., (2005) study used adults, whereas this present study included children who are most likely to require sedation/anaesthesia. Furthermore, unlike the 2009 study by Yuan et al., verbal interaction with the children during intervention was avoided to more closely simulate an actual MRI/fMRI scan.

The implications of the findings of this study are that behavioural intervention is effective to varying degrees with typically developing children aged five to eight years. While it did not have an effect on one child, there is promising evidence from the other five participants that behavioural intervention could be a viable option to sedation/anaesthesia. It is cost effective, may require only a session or two of intervention to be effective as two participants achieved a high level of stillness in this early phase, and the potentially dangerous side effects of sedation/anaesthesia can be avoided. However, there was not a large experimental effect for all participants.

There are a few possibilities why a clearer or larger experimental effect was not achieved for some participants. Two participants achieved a high level of stillness before the fourth treatment session, after which their movement levels incrementally escalated. P1 reached his maximum stillness during the third treatment session, and P3 reached her maximum peak stillness during the second treatment session. However, in the session(s) following, movement continued to increase. This could indicate that these participants had become habituated with the mock scanner and its picture presentation contingencies. Habituation is when responses to highly repetitive stimuli cease (Klingner, Nenadic, Hasler, Brodoehl, & Witte, 2011; Sokolov, 1963). Habituation would not directly increase motion, but the children would become unresponsive to the contingency, become bored and wiggle. A suggestion for further studies and/or mock scanner treatments would be to conclude the behavioural intervention once sufficient stillness has been achieved. Then the MRI/fMRI scan could be done before habituation sets in, thereby allowing for optimum stillness effect.

Another possible explanation would be that the participants had become satiated with the reinforcer. All participants had received the same sets of pictures for each session (baseline/familiarization and behavioural intervention) albeit in quasi-randomized orders. Perhaps several varying sets of picture presentations would have alleviated this issue.

Participant 5 took the cessation of the picture presentation, and its contingency, as a challenge. Her motion levels increased as treatment progressed and she stated she was trying to see how much she could move before the picture presentation would stop

playing. Perhaps additional discussion with such a child pertaining to the importance of an MRI/fMRI and the necessity of remaining motionless would be helpful in future studies. Moreover, feasibly more behavioural intervention session could be allotted for those needing more time to develop a sense of their movement and how to manage it. This study's protocol was four behavioural intervention sessions, but P5 may have benefited from extra sessions.

Another possibility for why the effects were smaller than anticipated could have been that the pictures and their uninterrupted viewing may not have been powerful reinforcers for the participants. If so, this would have weaken the response cost contingency or rendered it ineffective. The cartoons were shown for the one-minute sets, baby animals for the two-minute sets, and smiling faces for the four-minute set. One child commented that he would rather have more cartoon pictures than the smiling faces. Since the behavioural intervention is based on the avoidance of interrupting the picture presentation by remaining still, increasing the reinforcing value of the picture presentation should increase the effectiveness of the procedure. Perhaps future research could incorporate a preference assessment at the beginning of each session and the selected set of pictures would be used for the ensuing session.

Several limitations of the study should be noted. The pillow system used in this study was a prototype and as such displayed some idiosyncrasies which affected data and its acquisition. To avoid possible inconsistencies, prior to beginning this study the pillow's tubes were tested for air leaks by submerging them in water. Several leaks were discovered and sealed. However, later analysis of the sensitivities of the pillow tubes

revealed that each side of the pillow tubes appeared to have differing sensitivities. This was found in both horizontal (left side more sensitive than the right side) and vertical (upside more sensitive than the down side) data. However, data testing revealed the negative and positive values were reliable within themselves (i.e., over time).

Furthermore, there were some sets when the pillow system recorded incorrect data indicating an extreme amount of movement when motion was not observable. Before a set would begin, the sensitivity of the pillows were tested by the experimenter placing her hand on the pillows, applying varying pressures in alternate directions, and noting their data output. The pillow would function incorrectly one day or for one set and then correct itself for the next set or on another day. The cause of the finicky nature of the pillow was not ascertained during this research. Furthermore, three times during the recording of data more movement was being reported in the pressure pillow data than was actually being observed. These discrepancies were noted through observation and through reviewing the camcorder tapes after the completion of a set. In order to offset these discrepancies, the affected sets were repeated in order to obtain dependable data during a time period when the pressure pillow was functioning correctly, thereby not affecting project data.

Another limitation of the pillow system is that the motion measured by the system (values ranging from +1 to -1) is not converted to units in distance (e.g., mm). There were several failed attempts to relate the motion measurements from the pressure pillow to mm in order to determine the acceptability for an actual scan (head movement under two mm). Initially, simply marking the distance in mm on the pressure pillow was tried, but

heads are rounded and rulers are linear, therefore the measurements did not align. Another method involved using the weight of the participants' heads on the pressure pillow, but alas this also proved futile. Lastly, it was attempted to use film obtained from a camcorder placed over the head coil in the mock scanner by monitoring the amount of motion in those films. It was thought this motion could then be quantified and correlated with the pressure pillow data. Unfortunately, these two sets of data were not compatible.

Another limitation of the study was the duration was shorter for some sessions (up to a minute during the four minute set) when the picture presentation ended prematurely. This occurred during an average of two sets per participant of the earlier sessions in both baseline and intervention, as in the cases of P 1, P2, and P3. This was sometimes a technical issue when the presentation software would cease running and not resume, and sometimes an experimenter error when the picture presentation was stopped hastily with the experimenter believing it had reached the end of the picture presentation. The former was resolved by occasionally necessitating a set of pictures to be reshown to the participant during the session. The latter was resolved by adding a picture to indicate the conclusion of each set for both the participant and the experimenter. However, I believe that these instances did not affect the quality of the data since a large amount of data was available for analysis.

As the hand control pad was not connected, it did not record data. This limitation did not allow the contingency to be provided for movements stemming from pressing the buttons. Head motion accompanying pressing buttons, either reflexively such as twitching the head when a finger is pressing a button, or purposefully as nodding the head

for a sensed correct answer, was not addressed. While head motion in general was the focus, there was no data to indicate when the movement was associated with finger motion. However, visual observations noted when the child was concentrating on being still participants tended not to press the buttons to indicate when the green and red elves appeared on the screen. When they were concentrating on obtaining the correct answers by pressing the correct buttons there was more movement which seemed to increase for self-perceived incorrect responses, such as when a child would state, "oh no! I pressed the wrong button!", thereby moving their head back and forth as shaking of the head to indicate "no" Those children who wanted to press the correct buttons showed more motion and would talk about how they missed that last one, or they think they made a mistake. These actions would cause supplementary movement. It was observed the children who were able to lay the most still were not pressing the buttons as they were trying to be motionless. Further study where the button responses can be tracked and addressed immediately is necessary to ensure that the intervention is effective during scans when children are required to respond to task stimuli.

Ideally each participant should have had an actual fMRI scan following the behavioural intervention. Initially this was the plan for this study until the original setting, the National Research Council Institute of Biodiagnostics (NRC-IBD), closed its doors due to government cut backs. Thus, a limitation of this study is that we are unable to determine whether motion had been sufficiently reduced to permit a successful fMRI scan.

Similarly, future research for other peoples often given sedation/anesthesia routinely for MRI/fMRI such as people diagnosed with, or suspected of having Alzheimer's disease, and people diagnosed with intellectual disabilities. Despite the limitations noted above, the intervention showed promise for five out of six participants. Future research is warranted to replicate and evaluate whether the observed effects are sufficiently large enough to produce an MRI/fMRI scan in a clinical environment.

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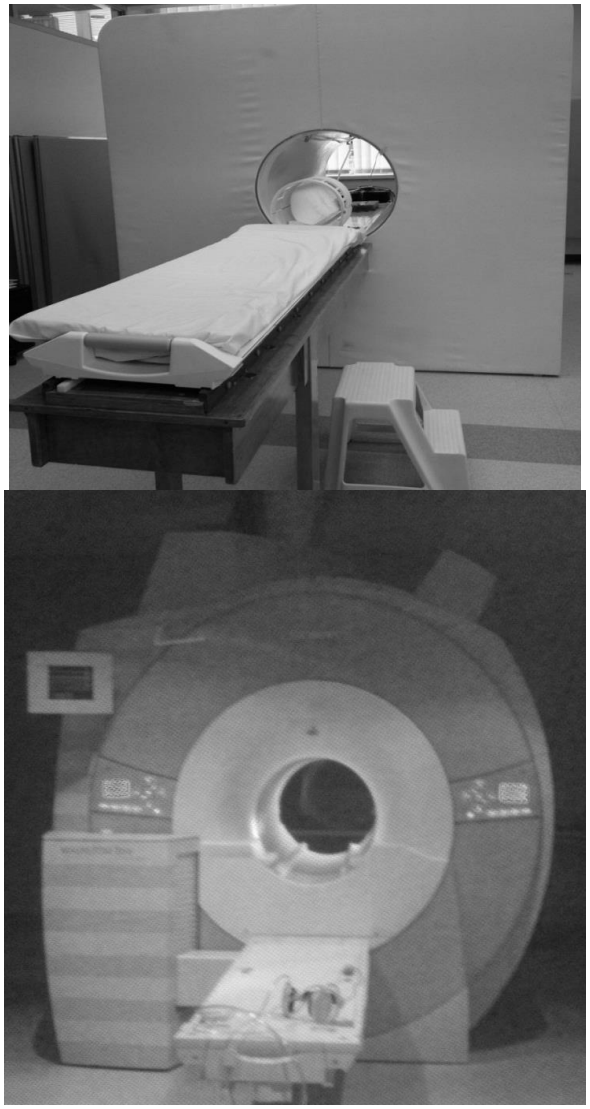

Figure 1. MRI and mock scanner comparison. The top photo is the MRI used at NRC-IBD. The lower photo is of the mock scanner at NRC-IBD. Pictures taken by Deborah Hatton.

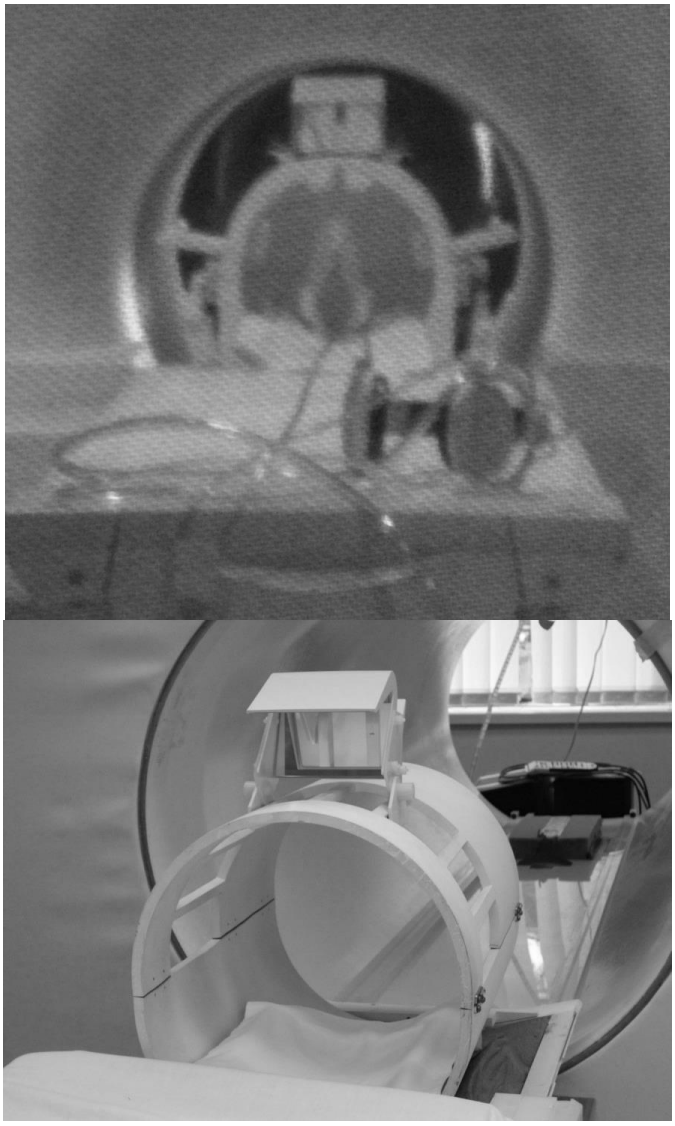

Figure 2. MRI and mock scanner helmet comparison. The top photo is the MRI helmet used at NRC-IBD. The lower photo is of the helmet used in the mock scanner at NRC-IBD. Pictures taken by Deborah Hatton.

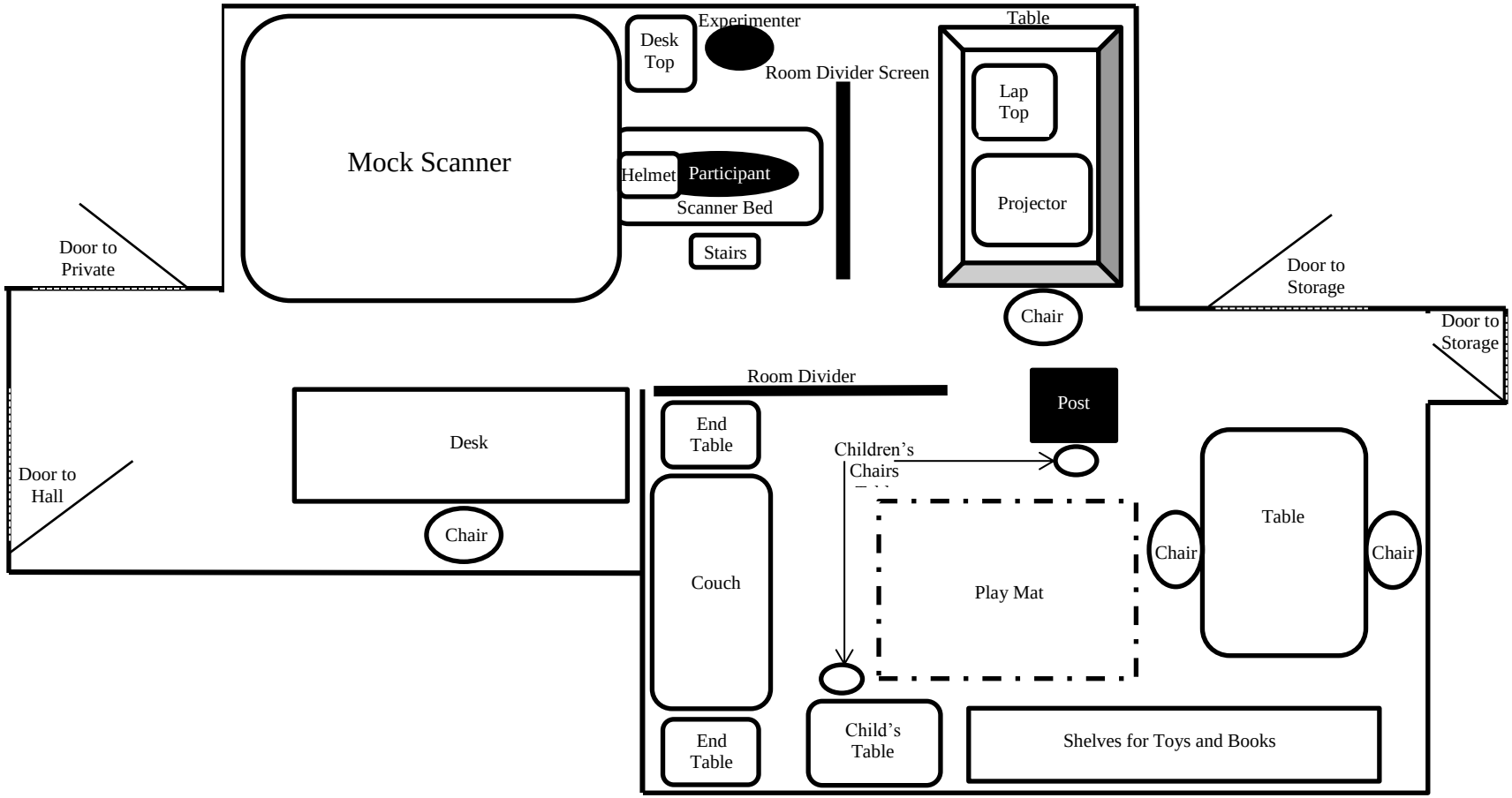

Figure 3. Schematic drawings of a bird's eye view of the mock scanner research area and room.

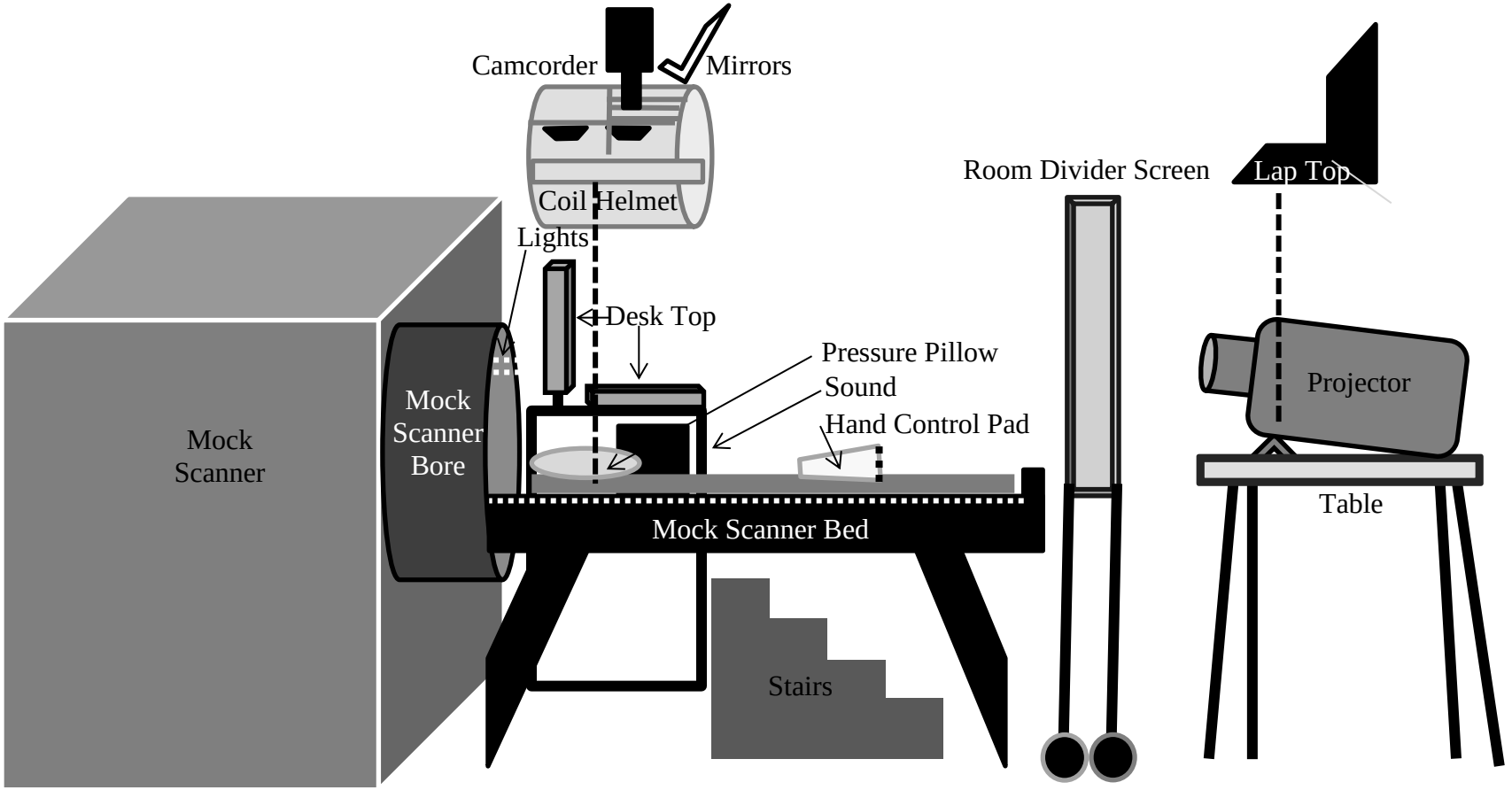

Figure 4. Schematic drawings of a front view of the mock scanner research area.

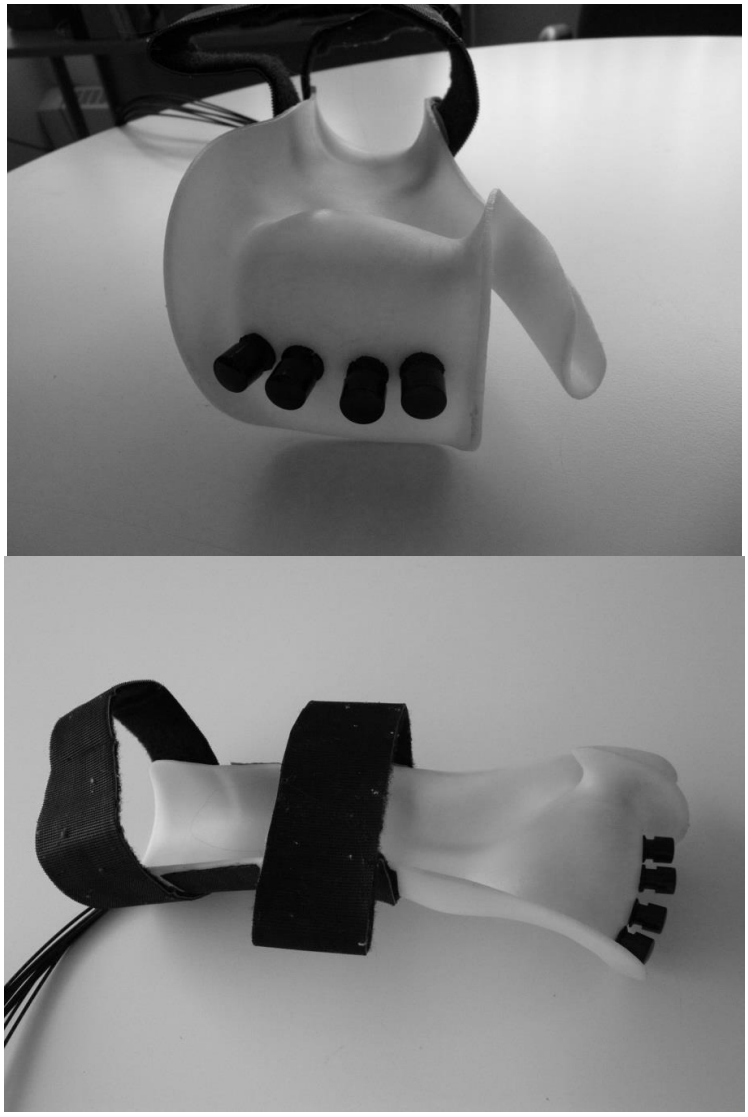

Figure 5. The hand held response pad used in the mock scanner at St.Amant Research Centre. The hand is securely held in place by the two Velcro straps, thereby enabling the fingers to comfortably manipulate the 4 buttons in response to questions. Pictures taken by Deborah Hatton.

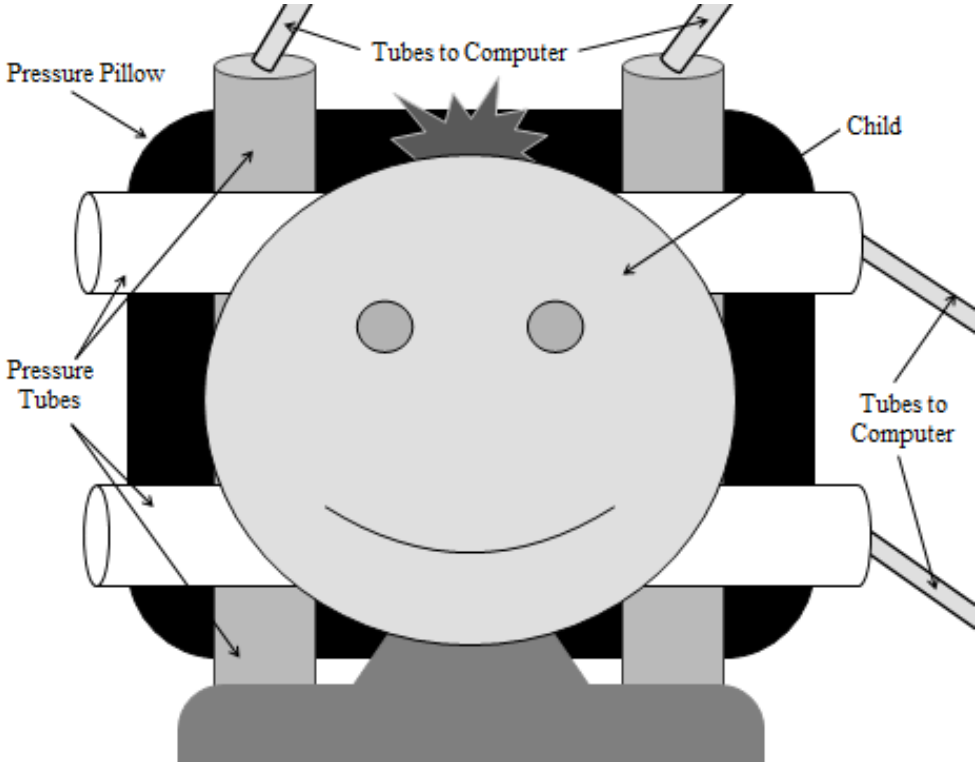

Figure 6. The pressure pillow apparatus set-up. The child placed his/her head on the pillow. A series of tubes measured the amount of pressure displayed whenever the child moved his/her head in any direction. Data was sent to a computer approximately every one seventh of a second.

Figure 7. Pictures of the red (right) and green (left) elves. The task the children were asked to complete involved pressing their first finger when the red elf appeared, and pressing their second finger when the green elf appeared. Pictures created by Johnathan Hatton.

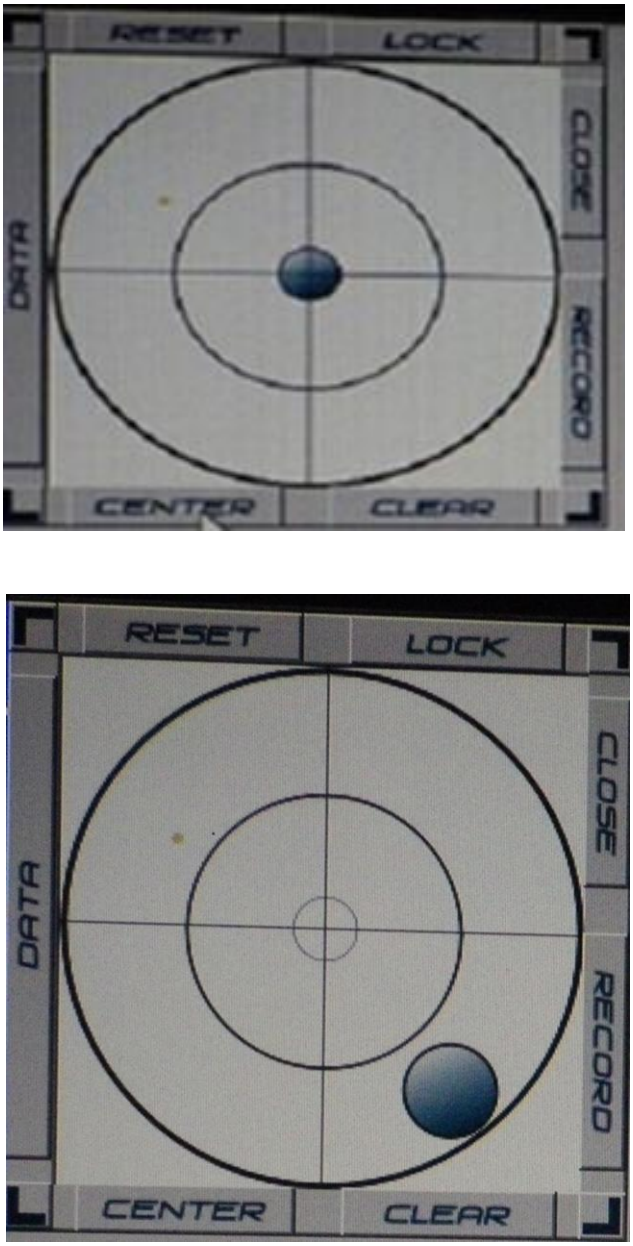

Figure 8. The computer display screen generated by the pressure pillow. The top picture shows the ball centred, and the bottom picture shows movement outside of the accepted perimeters. Pictures taken by Deborah Hatton.

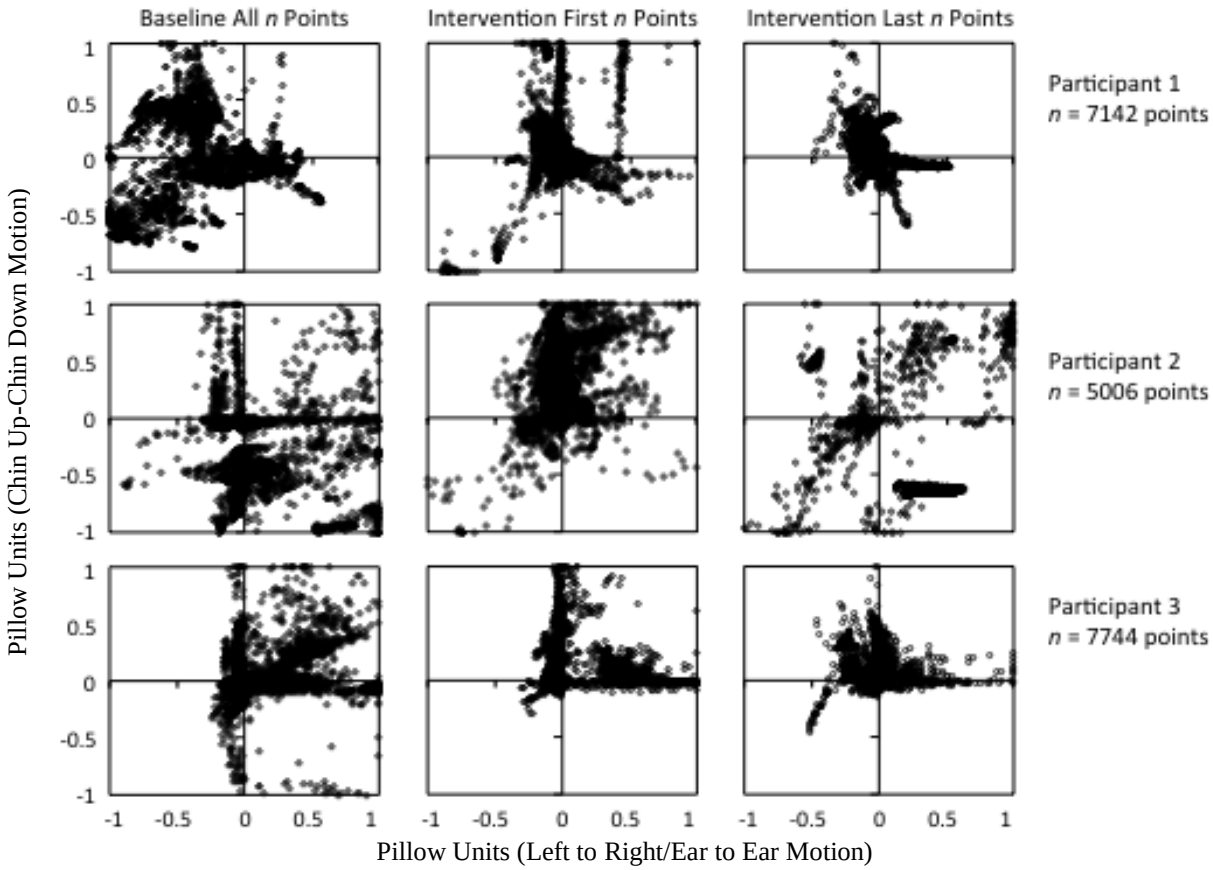

Figure 9. Scatter plot of head motion for Participants 1 through 3. Baseline (left graph), beginning of Intervention (middle graph), and end of intervention (right graph). All baseline data points equal *n*.

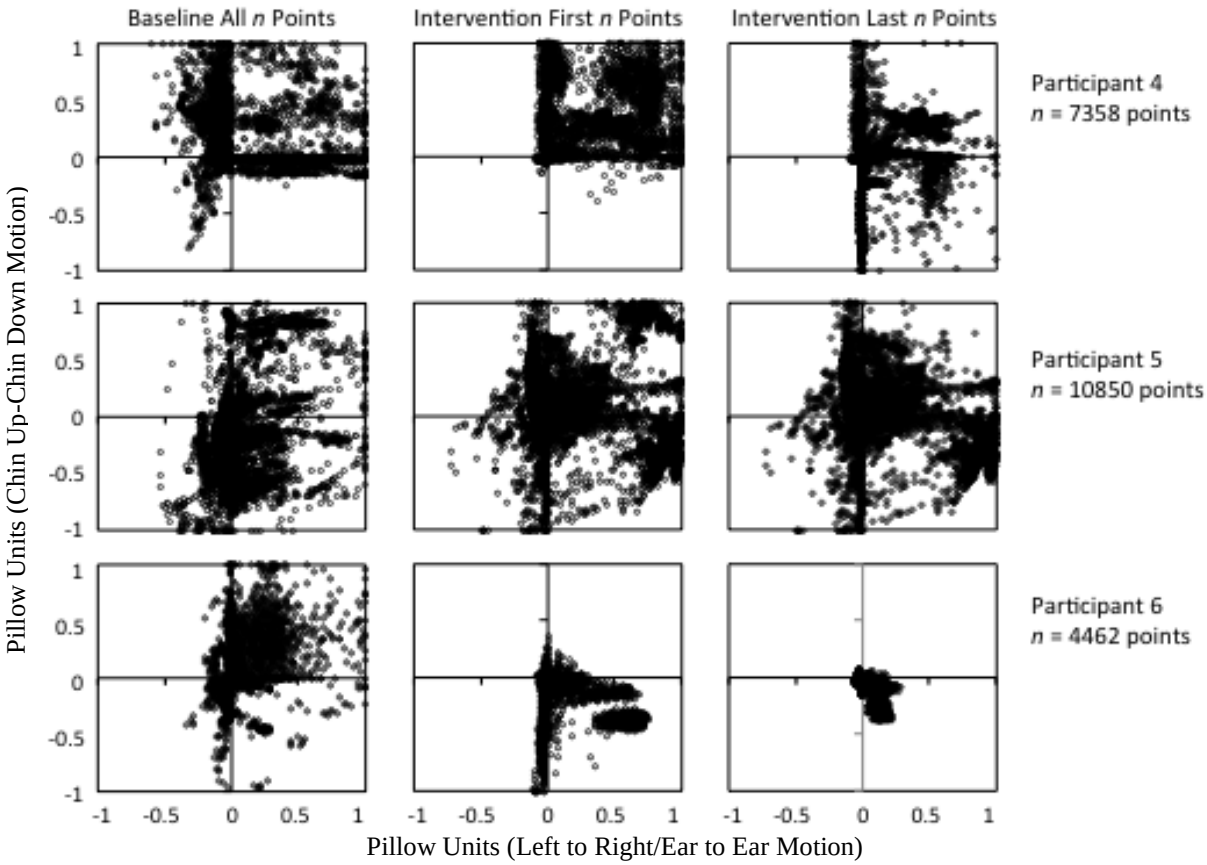

Figure 10. Scatter plot of head motion for Participants 4 through 6. Baseline (left graph), beginning of Intervention (middle graph), and end of Intervention (right graph). All baseline data points equal *n*.

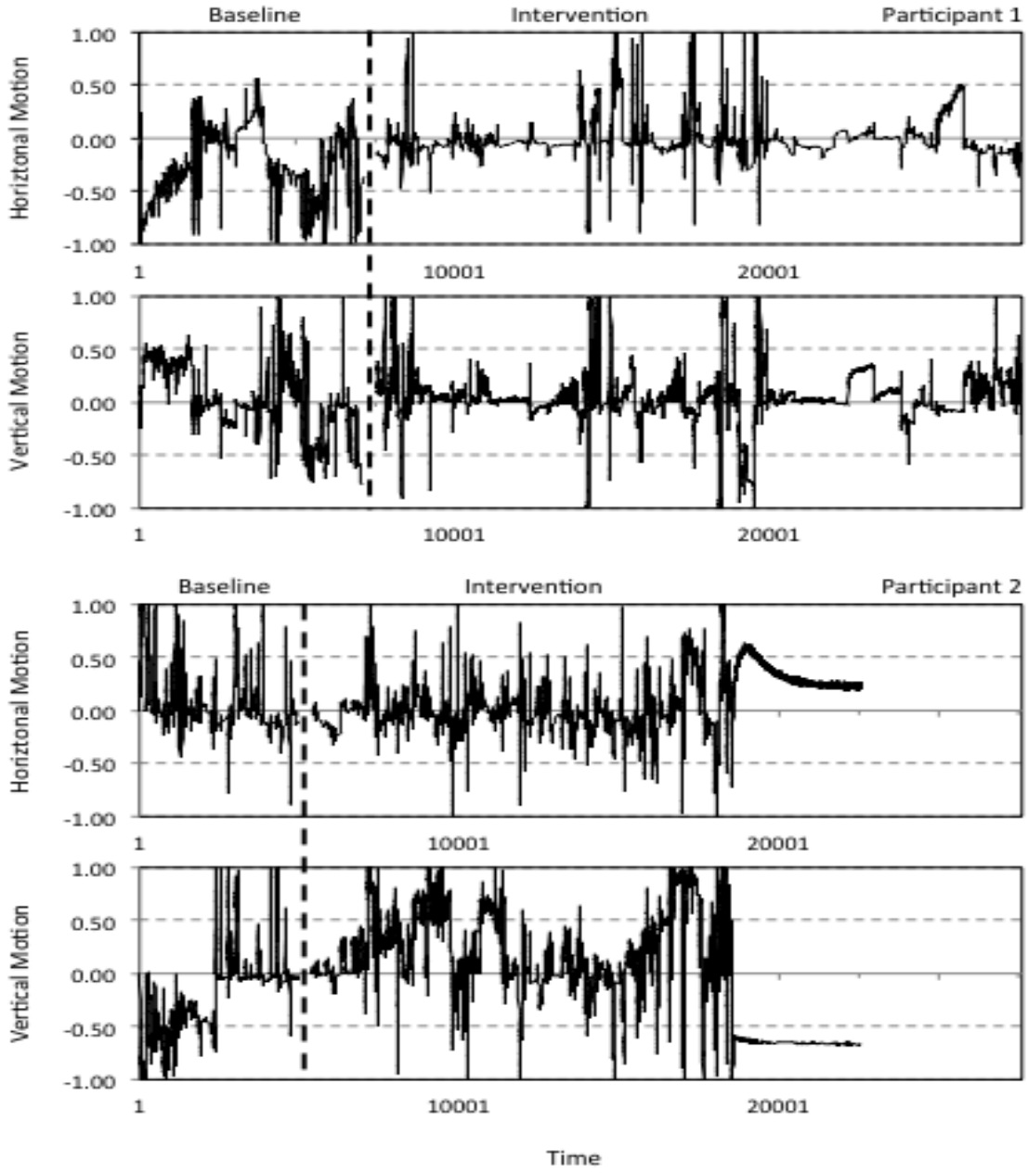

Figure 11. Horizontal and vertical head motions for Participants 1 and 2. Baseline and intervention across all sessions.

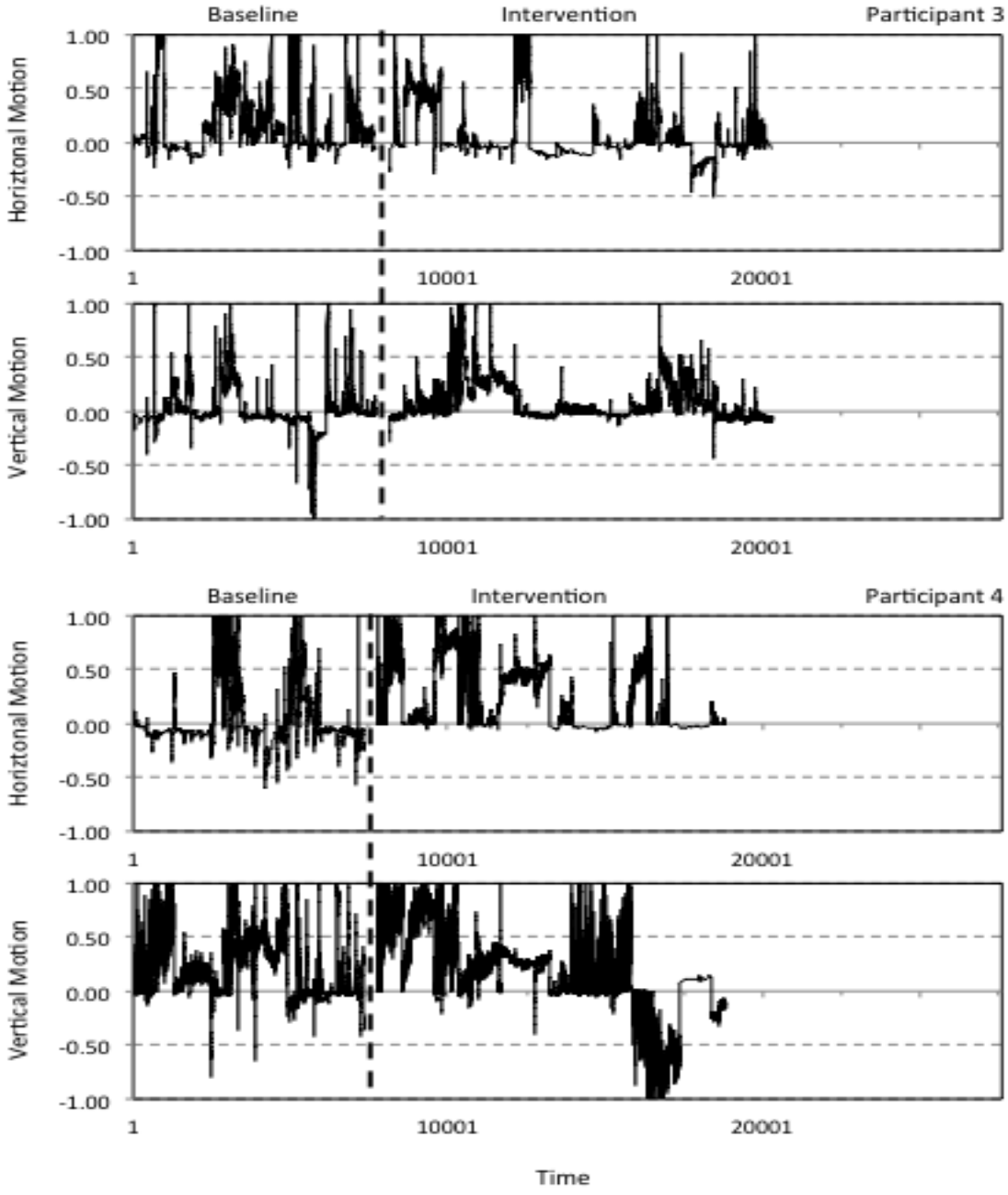

Figure 12. Horizontal and vertical head motions for Participants 3 and 4. Baseline and intervention across all sessions.

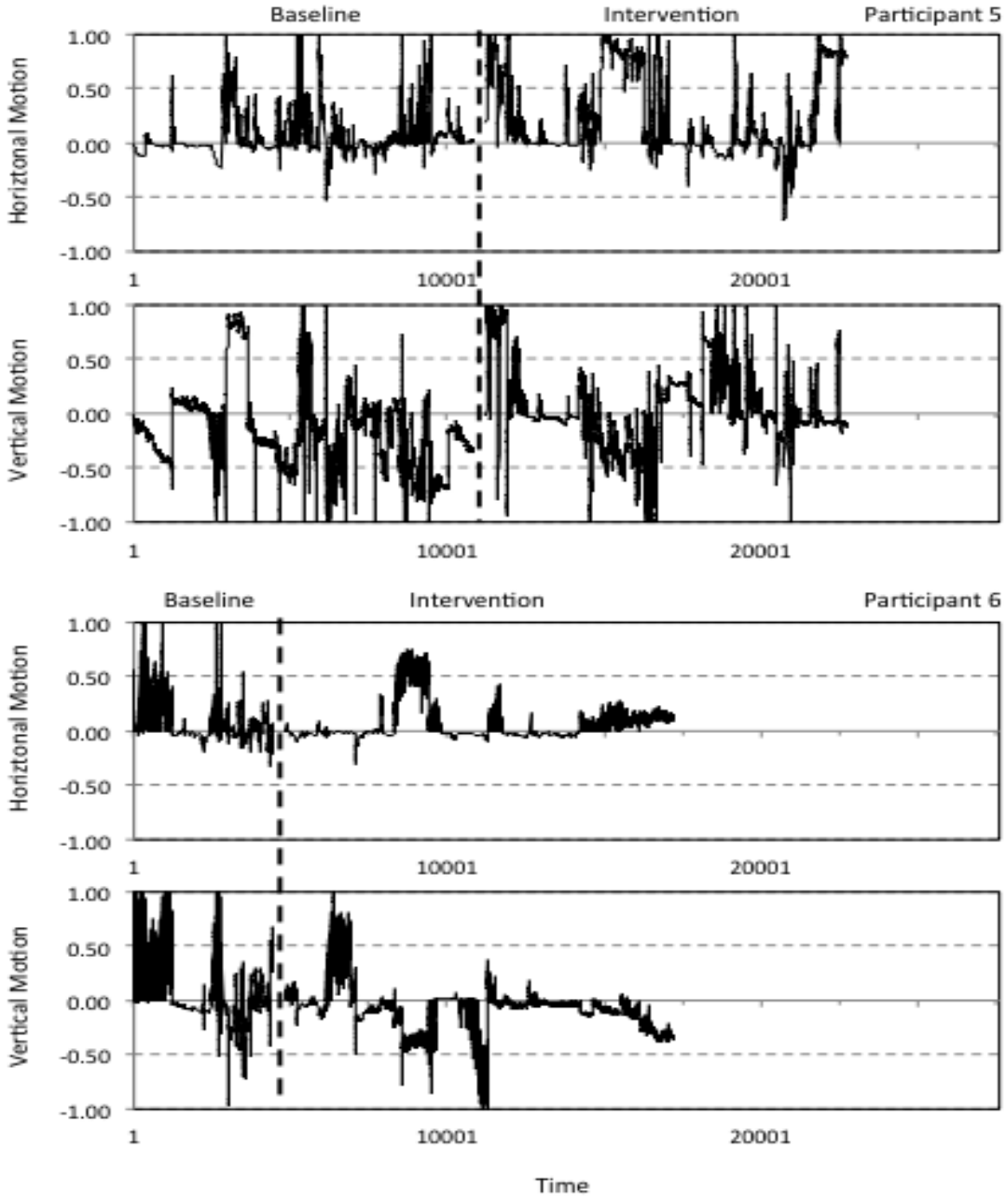

Figure 13. Horizontal and vertical head motions for Participants 5 and 6. Baseline and intervention across all sessions.

Appendix A

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Recruitment Script for Research Study

I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children during MRI and fMRI"

"Hi, _____ (Name of Parent), this is Deborah Hatton calling from the St.Amant Research Centre. I am calling regarding _____ (Name of child)'s visit to the NRC Institute for Biodiagnostics on _____ (Date). At that time you had indicated during our interview that you would be open to being contacted about future studies. Is this something you may still be interested in?"

If NO then: "Well, I hope you had a good experience with us and I just want to thank you and your son/daughter/children once again for having participated in our past research study. We hope it was a fun and interesting experience. Thank you so much. Good bye."

If Yes then: "Ok, Great! Please let me explain what our present study is about. For my thesis study we are looking at typically developing children, aged 4-8. As you are aware from the previous MRI study, children often have some issues surrounding MRIs including remaining still during scanning. This study uses behavioral methods to teach children to stay still so they can tolerate an MRI/fMRI without the use of sedation. As in the last study_____ (Name of child) will be asked to use the mock scanner as in the previous study, but this time he/she will watch a video. The behavioural method is that when he/she lies still the video will play, but when he/she moves the video will shut off for 5 seconds. Is this a study you and _____(Name of child) would be interested in?

If NO then: "Well, thank you for your time and I hope you had a good experience with us and I just want to thank you and your son/daughter/children once again for having participated in our past research study. We hope it was a fun and interesting experience. Thank you so much. Good bye."

If Yes then: "Great! I will send you a package containing some information for you to read, and I will call back next week to answer any questions you may have. Are you still at the same address? Ok. Thank you. Good bye. "

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Appendix B

Recruitment Letter to Parents of Prospective Participants

DATE,

Dear _____ (*Parent`s Name)* of _____ (*Child`s Name)*:

As I had mentioned on the phone on _____ (Date) I am enclosing information about a mock Magnetic Resonance (MR) Imaging study being performed by myself and other researchers from the University of Manitoba and the St.Amant Research Centre.

This study is called **"I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children during MRI and fMRI"** and will be performed at the St.Amant mock scanner facility.

Please:

1. Read the enclosed material. It contains information that we hope will answer any questions you may have regarding your child's participation in this study. If this does not answer all your questions, please feel free to call us.
2. Carefully review the list of medical conditions that might exclude your child from this study. This is mainly for his/her safety. If your child meets any of the exclusion criteria, you should not enter the study. If you have any questions or concerns, we will be glad to help you address them.
3. Please allow yourself at least 24 hours after reading the information in this package before scheduling an appointment for this study**. I will be contacting you regarding your child's participation, however, if you wish, you may call me; Ms. Deborah Hatton, at 204-333-5408 to arrange a date and time**.
4. If you have any questions or concerns, please telephone either myself at, **Ms. Deborah Hatton, at 204-333-5408,** or **Dr. C.T. Yu, at 204-256-4301 extension 5399, or 204-474-9453**, and we will either answer your questions directly or make a referral to an appropriate member of the research team.

Sincerely,

Deborah Hatton,
Researcher, Master of Arts Student
University of Manitoba

Dr. C.T. Yu
Professor, Supervisor
University of Manitoba

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Appendix C
Project Description, Consent, and Assent to Participation Form

I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children during MRI and fMRI

Principal Investigator
Ms. Deborah Hatton, B.A. Hons.,
Master of Arts Student
University of Manitoba,
umhattod@cc.umanitoba.ca

Collaborator
Dr. C.T. Yu
Professor, Supervisor
University of Manitoba;
Director of Research
St.Amant Research Centre
ct.yu@ad.umanitoba.ca

You are being asked to consent to your child's participation in a research study. Please take your time to review this Research Study Summary and Consent Form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with your regular doctor, friends and family before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

WHAT IS THE RESEARCH ABOUT?

This project is designed to help teach children to stay still during MRI, a problem encountered in paediatric MRIs used for diagnosing illness/injury and in research studies. Motion causes the MR images to be of poor quality and reduces their usefulness. Being able to stay still will eliminate the necessity for sedation which is often used to aid children in tolerating an MRI/fMRI.

AM I ELIGIBLE TO PARTICIPATE?

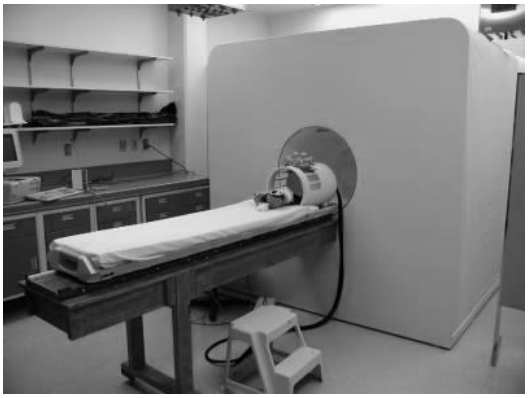
We are recruiting Typically Developing Children between the ages of 4 and 8.

This study is voluntary. If you decide not to participate in this study or you withdraw from the study, your normal medical care will not be affected in any way.

WHAT WILL MY CHILD HAVE TO DO?

Mock Scanner Familiarization Training. We will be using the same mock scanner your child was introduced to at the Institute for Biodiagnostics. It is presently housed at the St.Amant Centre. This study will determine the amount of

movement reduction that can be achieved simply by becoming familiar, and more comfortable, with the scanning environment as presented in a mock scanner (see picture below) to control for motion.



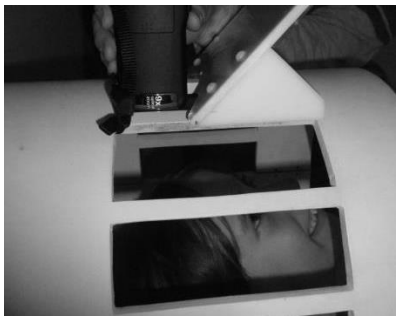
This is a picture of the mock or pretend MRI facility at the St.Amant Research Centre. The stuffed animal shows the position of the child on the scanner bed during part of this study.

Children will be asked to lie as still as possible on the bed, inside the pretend scanner's main bore. Images will be projected onto a screen attached to the foot of the pretend MRI bed, permitting the child to watch video pictures. Pictures of cute baby animals, families, gatherings of people, and stills from favourite cartoons will be presented. Children will have a hand control response pad (much like on a video game) on their hand, and will be asked to react to stimuli within the video (see picture below). Children will be asked to perform a two finger response task. Questions such as, "Press the first finger button when the elf wearing the colour red appears on the screen" and "Press the second finger button when the elf wearing the colour green appears" will be asked. As these tasks are being presented, motion levels will be monitored using a specially designed pillow with four divisions to electronically relay motion (up, down, and both sides) which will be placed under the child's head. The pillow will record analogue data for conversion into digital data by means of a microcomputer measuring movement in millimeters. We will do this up to 4 times to see if Familiarization Training alone is sufficient to allow the child to tolerate an MRI/fMRI.

This is a picture of the hand held response pad. The Velcro strap keeps it on the arm while fingers are free to press the buttons in response to questions.

In addition, a video camera will be mounted on the helmet-type head coil to monitor motion by filming a small adhesive dot placed in the centre of the child's forehead. The forehead will be the only part of the child being filmed. No identifiable information will be gathered on the video tape. Parents and their children will be able to view the tapes should they request it. The video recordings will only be collected and viewed by the researchers and will be kept inside of a locked room having

restricted access. Videos of the children's foreheads may be included in publications and/or presentations. Tapes will be destroyed after the research has been published.



This picture demonstrates the positioning of the video camera above the forehead of the child.

2. Behavioural Training. For some children simply being familiar with the room and scanning process may not be enough to reduce movement during an MRI. These children will also receive Behavioural Training. Behavioral training will be similar to Familiarization Training. For example, training will still take place in the mock scanner's main bore. Children will have a hand control response pad on their hand, and will be asked to react to stimuli within the video. The same system will be used to record how much the child moves. In addition, children will receive a behavioural intervention designed specifically to reduce their movement. Behavioural treatment will consist of a 5 second loss of access to the video as a form of feedback for excessive movement. Training sessions will continue until the child demonstrates a low average movement rate or until the maximum number of sessions has been reached.

IS THE STUDY CONFIDENTIAL?

Normally, only people directly involved with the research procedure are allowed in the study area. All staff at the St.Amant Centre are required to keep health information confidential, in accordance with the Personal Health Information Act of Manitoba.

Information gathered in this research may be published or presented in public forums; however neither your name nor your child's name will be used or revealed. Medical records that contain your child's identity will be treated as confidential in accordance with the Personal Health Information Act of Manitoba.

All data obtained during the child's scan will be stored with an alphanumeric code instead of his or her name. Only the child's file, which is kept in a locked office, will have information that relates his or her name to the code, so that information regarding your personal identity and your child's identity will be kept confidential. Your personal information or that of your child may be disclosed if required by law due to noted abuse or neglect.

Organizations that may inspect and/or copy your research results for quality assurance and data analysis include groups such as the Psychology/Sociology Research Ethics Board, University of Manitoba.

WHAT ARE THE POSSIBLE HARMS OR BENEFITS?

Some people may have a feeling of claustrophobia while they are in the mock scanner, and in extremely rare cases this feeling seems to have triggered a more persistent claustrophobia. If your child indicates

feeling fear, claustrophobia, or panic, we will withdraw him or her from the situation immediately, and re-evaluate participation with you.

No long-term adverse effects of the mock scanner have been reported. We would contact you if any new risks are discovered.

Although this is a research study, your child will also personally benefit by participating. The ability to stay very still for an examination may one day be helpful during an actual clinical MRI scan, and may generalize to other medical situations and procedures. The results of this study may also benefit other children who require medical imaging procedures.

WHAT ELSE SHOULD I KNOW?

You have the right to withdraw from the research study at any time and for any reason. We will remind you and your child of this right prior to every session, and will ask you and your child if you would like to withdraw should he/she display any behaviour that indicate he/she wants to stop the experimental procedures (e.g., negative vocalizations, crying etc.).

The investigators reserve the right to end your participation for any reason, such as if the child is not verbalizing anxiety but is demonstrating such behaviour.

We will give you $10 for each pretend scanner visit to cover any expenses you incur for your child to participate in this research study. Parking is provided at the St.Amant Centre for a minimal charge.

Please contact us if you would like any more information about the study.

Please let us know if you would like copies of any published scientific reports about the research project.

HOW CAN I GET MORE INFORMATION?

The following people may be contacted for additional information:

Deborah Hatton,
Principal Investigator,
Master of Arts Student at University of Manitoba,
204-333-5408

Dr. C.T. Yu,
Co-Investigator, Supervisor,
Professor at University of Manitoba,
Director of Research at St.Amant Research Centre.
204-256-4301 extension 5399, or 204-474-9453

For questions about your rights as a research subject, you may contact:

Psychology/Sociology Research Ethics Board,
University of Manitoba,
204-474-7122

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Appendix D
Recruitment Script Follow-up for Research Study

I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children during MRI and fMRI"

"Hi, _____ (Name of Parent), this is Deborah Hatton calling from the St.Amant Research Centre. I am calling regarding the package I sent you last week about including _____ (Name of Child) in my M.A. theses study involving an MRI mock scanner.

Have you had a chance to review the information?

If NO then: Would you like me to give you time to read the material in the package and call you back next week?

If NO then: "Well, I hope you had a good experience with us and I just want to thank you and your son/daughter/children once again for having participated in our past research study. We hope it was a fun and interesting experience. Thank you so much. Good bye."

If YES then: "Ok, great. What is a good time for me to call back? Ok I look forward to speaking with you next week on _____ (date and time) to answer any questions you may have. Thank you. Good bye.

If YES then: "Do you have any questions about the study?" If YES then questions will be addressed. Then: "Is this research something you may still be interested in?"

If NO then: "Is this research something you may still be interested in?"

If NO then: "Well, I hope you had a good experience with us and I just want to thank you and your son/daughter/children once again for having participated in our past research study. We hope it was a fun and interesting experience. Thank you so much. Good bye."

Subject number: _____
 Initials: ____

If Yes then: “Ok, Great! What is a good time for you and _____(Name of Child) to meet me at St. Amant? If you have any questions or need to reschedule, please feel free to call me at 333-5408. Ok I look forward to seeing you both on _____ (date and time). Thank you. Good bye.

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Appendix E

I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children during MRI and fMRI

Consent Form

I have received a copy of and I have read the Research Study Summary. I understand the nature of the study, including the potential risks and benefits. I have had adequate time to consider the information. I have talked to Deborah Hatton and/or her colleagues. All my questions about the study have been answered. If I have any more questions, I may call Dr. C.T. Yu, 204-256-4301 extension 5399, or 204-474-9453. I understand that I will be sent a copy of this consent form, after signing it.

I understand that information regarding my personal identity and my child's identity will be kept confidential. I agree to the inspection of my research records by the Psychology/Sociology Research Ethics Board, University of Manitoba. I give permission for access to the diagnostic and demographic information (age, vision problems, diagnosis, level of functioning and previous IQ and adaptive behaviour assessments if any) from the health records held at NRC-IBD.

I realize that by signing this document I am not waiving any legal rights.

I hereby agree to the participation of my child, _____, in the research protocol, **"I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children During MRI and fMRI",** and I understand that I can end participation at any time and for any reason. If you wish to receive a summary of results, it will be sent to you approximately 04/2014.

I wish to receive a summary of results: Yes □ No □

My consent has been given freely.

_____ _____ _____
Name of parent/guardian (Print) Signature of parent/guardian Date

I agree to be contacted should I be interested in having my child participate in future studies. I understand that such an agreement is optional, and that neither agreeing nor disagreeing will have any effect on the health care received by my child.

_____ _____ _____
Name of parent/guardian (Print) Signature of parent/guardian Date

_____ _____
Name of person obtaining consent (Print) Role in study *(e.g. Investigator)*

_____ _____
Signature of person obtaining consent Date

Subject number: _____

 Initials: ____

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Appendix F
Research Study Summary and Assent Form for Children

"I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children during MRI and fMRI"

WHAT IS THE RESEARCH ABOUT?
We can look at the way the brain looks using something called Magnetic Resonance Imaging or MRI. To get good pictures you will need to lie very still in a machine and not be wiggly, so we're going to measure how much you move in a pretend machine and show you a video when you're doing well.

WHAT WILL I HAVE TO DO?
You will go to a pretend MRI to see how it works and to practice lying very still. There you will watch a video. You will watch a movie while you are lying down, and try to stay very still while you are inside. If you move too much, you won't see the movie anymore. When you are very still, the movie will play. We'll ask you questions about how you feel while you are in the pretend MRI.
We'll work together for about an hour at a time, and we might finish in as few as two visits, or it might take us as many as four visits.

ARE THERE GOOD THINGS OR BAD THINGS ABOUT THE STUDY?
During the study we might ask you to do something that makes you feel scared. If that happens, just tell us and we'll stop. If everything works out, you'll be able to stay still in the future without someone giving you medicine that makes you sleepy.

CAN I DECIDE IF I WANT TO BE IN THE STUDY?
Nobody will be angry or upset if you do not want to be in the study. You can ask questions anytime and if there is a problem or you do not want to do the study, we won't do it.

_____	_____
Signature of child providing assent	Date
_____	_____
Name of person obtaining consent (Print)	Role in study *(e.g. Investigator, MR Technologist)*
_____	_____
Signature of person obtaining consent	Date

Subject number: _____

 Initials: ____

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Appendix G

Procedural Reliability

I'm Still Here: Behavioural Interventions to Control for Motion with Typically Developing Children during MRI and fMRI

Date: _____ Participant:_____

Experimenter: _____ Recorder:_____

SESSION			
Type of Picture Presentation (Cartoon, Animals, People)			
Did the Experimenter:			
Have Parent(s) Sign Consent Form			
Have Child Sign Assent Form			
Place Square Sticker on Child's Forehead			
Apply Earplugs/Headphones to Child			
Adjust Pillow			
Adjust Camera			
Start Camera			
Attach Hand Pad on Child's Arm			
Administer Verbal Instructions to the Child			
Reset Data Screen Before the Set			
Set the Sound			
Put the Lights on in the Bore			
Give the Honourarium to the Parent(s)			
Give the Child their Tangible Reinforcers: ____ Toy,			
____ and Edible			