BSc in Psychology

Intervention on Parkinson Disease Symptoms with Optical Illusion Visual Cues in Augmented Reality Software

Month 05, Year 2017

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Foreword

Submitted in partial fulfillment of the requirements of the BSc Psychology degree, Reykjavík University, this thesis is presented in style of an article for submission to a peer-reviewed journal.

Abstract

Parkinson disease (PD) is the second most common, continuous degenerative neurological disorder that manifests itself as different motor and non-motor attributes, such as gait deficiencies and attention deficits. There is no permanent cure for PD, only symptom relief. Kinesia paradoxica naturally resides within the Parkinson patient, when stimulated, it relieves symptoms of Parkinson. This study aimed to stimulate kinesia paradoxica with visual cues in Augmented reality software (AR). Single subject ABA withdrawal design was performed on one PD patient who matched controls for the study. Subjects from a nursing home in Iceland volunteered, where the measurements took place, after an introductional letter from a physical therapist. The GAITRite electronic walkway was used for reliable measurements of Functional Ambulation Performance (FAP; a quantitative gait measure). The intervention was a software creation of AR application for use on mobile devices that filtrates the ground and portray the illusion of a staircase. Accumulated 12 measurements on the GAITRite walkway were reported in this study. Results showed that the AR visual illusion of a staircase had a reverse effect on gait performance. Limitations such as time constraints of measurements, group sensitivity and programming failure, resulted in excluded subjects, as well as lack of reliability and validity in findings.

Útdráttur

Parkinson sjúkdómur (PS) er næst algengasti samfelldi taugahrörnunarsjúkdómurinn, sem lýsir sér í mismunandi hreyfi- og ekki hreyfieinkennum, líkt og truflað göngulag og athyglisskerðing. Það er engin varanleg lækning við PS, einungis er hægt að halda einkennum í skefjum. Kinesia paradoxica er náttúrulegt fyrirbæri sem býr innra með Parkinson sjúklingnum, þegar það er örvað, þá léttir það á einkennum Parkinson. Þessi rannsókn miðaði að því að örva kinesia paradoxica með sjónrænum bendingum í gagnauknum veruleika hugbúnaði. Einn þátttakandi sem greindur var með PS var tekinn fyrir í einliða vendisniði, ABA. Þátttakandi af öldrunarheimili á Íslandi bauð sig fram eftir að hafa verið upplýstur um rannsókn frá sjúkraþjálfara með kynningarbréfi. GAITRite göngugreiningarmotta var notuð til áreiðanlegra mælinga á álagsþrýsting (FAP, mælikvarði á heildar göngulagi). Inngripið var hugbúnaður í gagnauknum veruleika í spjaldtölvu, sem sýndi heiminn eins og hann er í raun, fyrir utan sjónrænar vísbendingar sem sjónblekking af stiga. Það voru gerðar 12 mælingar á GAITRite göngumottu í heildina. Niðurstöður sýndu að inngrip hafði gagnvirk áhrif á göngulag. Takmarkanir á borð við lítinn tíma til mælinga, viðkvæmur hópur og örðugleikar við hugbúnað, leiddu til útilokunar á þátttakendum, sem og skorti á áreiðanleika og réttmætis í niðurstöðum.

Intervention on Parkinson Disease Symptoms with Optical Illusion Visual Cues in Augmented Reality Software

The ability to control movement is crucial to quality of life and performance. Parkinson's disease (PD) is the second most common, continuous degenerative neurological disorder that presents itself in different motor and non-motor characteristics (Tanner & Goldman, 1996). 6.3 million people worldwide are afflicted and about 1% of the population over 60 years of age (Nussbaum & Ellis, 2003).

There is no durable cure for PD, only symptom relief. Symptoms of PD are extremely attenuating with the advancement of the disease. Motor symptoms include tremor at rest (Jankovic, 2007), rigidity, postural instability, flexed posture, akinesia/bradykinesia and freezing of gate. Non-motor symptoms, for example, can produce deficits in the working memory capacity (Wolfe et al, 2009), resulting in incapacity to sustain a goal when interruption is in place.

There is broad research on what may cause the disease (Shafique, Blagrove, Chung & Logendrarajah, 2011) genetic component, mutative gene (Liu, Aliaga & Cai, 2012), oxidative stress (Dagdelen, Akkaya & Genc, 2013) and exposure to environmental toxins (Nicoletti, Pugliese, Nicoletti, Arabia, Annesi, De Mari, Zappia, 2010).

However, this research is based on correlational results. Nevertheless, what is established knowledge concerning the PD brain, is the shortage of dopamine neurotransmitters in the substantia nigra (Shafique et al., 2011).

Lack of knowledge regarding what may cause PD, translates into the lack of diagnosis and treatment. Diagnosis is made by a neurologist with self-administered questionnaires (Dahodwala, Siderowf, Baumgarten, Abrams, & Karlawish, 2012) that depend on patient recall, thus inducing bias, for memory recollection is unreliable and feasible to manipulation (Ramirez et al., 2013).

However, gait analysis systems provide more accurate representation of gait and have proven to be more accurate than clinical tests (Gouelle, 2014). An objective reliable measurement of gait in PD is the GAITRite walkway (Cho, Lee & Lee, 2015; Nelson et al., 2002). The walkway system analyses specific components of the ability to walk from one place to another, to provide a single, numerical value that represents gait, the Functional Ambulation Performance Score (FAP; a quantitative gait measure).

Prevalent drug treatment for PD is the pharmaceutical Levodopa, an antecedent of the neurotransmitters dopamine (Ferreira et al., 2015). However, it has limited duration, it does not eliminate PD symptoms and within five to ten years from prescription of the drug, it becomes non-effective. Additionally, side effects are immobilizing, bringing forth the "ON/OFF phenomenon" (Fasano et al., 2012).

PD is difficult to comprehend, whether it may be the symptoms, cause or treatment. However, kinesia paradoxica, is a phenomena, that naturally resides within PD patient (Ballanger et al., 2006). It manifests itself with the ability to perform complex movements easily, or re-initiate a movement with goal oriented visual and/or auditory cues. Additionally, three PD patients self-discovered the effect of visual cues by turning a walking cane upside down and attempting to step over the handle, resulted in improved gait (Dunne, Hankey, & Edis, 1987). However, another study showed that horizontal lines placed on a walking path with regular intervals, improved gait more than the use of a upside down cane (Dietz, Goetz & Stebbins, 1990). Also, a study reported gait improvement with taped step length markers as a visual cue (Lewis, Byblow, & Walt, 2000).

However, a single case report showed that 2-dimensional cues such as lines on floor were ineffective (Snijders, Jeene, Nijkrake, Abdo & Bloem, 2012), while responding well to 3-dimensional cues in alleviating gait disabilities. Furthermore, a product designer constructed a 3-dimensional staircase illusion that alleviated freezing of gait (FOG) (Janssen, Soneji, Nonnekes, Bloem, 2016). Soneji et al (2016), in a single case study, targeted the symptoms of FOG, and its relation to kinesia paradoxica, by designing an optical illusion of a grayscale coloured staircase in illustrative forms. The staircase illusion was then laid on the floor as a goal oriented cue. The PD patient walked effortlessly across the floor, relieving symptoms of FOG. Additionally, kinesia paradoxica was stimulated with virtual cueing spectacles (VSC) (Kaminsky, Dudgeon, Billingsley, Mitchell & Weghorst, 2007). An ABA single subject design study on six subjects, revealed decreased length and number of FOG episodes when the subjects used virtual cueing spectacles in their home for one week or more. The virtual cue consisted of horizontal lines in form of a light display in glasses. Results stated, that number of freezing episodes decreased for most patients. Withal, lifestyle factors are difficult to control in community based studies.

However, another study compared real transverse line cue placed on the floor, to three different virtual visual cues presented in virtual reality glasses (Griffin et al., 2011). Results found that transverse line cue improved gait ability, while none of the virtual reality cues improved gait except visual flow, but only moderate improvement. Nonetheless, a study submitting 15 PD patients to a full virtual reality scenario with visual downward displacements on a staircase improved postural ability (Yelshyna et al., 2016). A longitudinal, randomized controlled trial on 42 PD patients, implementing VR-augmented balance training compared to conventional balance training and control group (Yen et al., 2011). The study showed that both VR-augmented balance training and conventional balance training improved postural control with sensory assimilation in PD patients.

The main purpose of this study was to reduce PD gait variability with a non-invasive approach. The manipulation of the phenomena kinesia paradoxica with visual cues, that required programming a demo application in augmented reality, portraying a specific illusion of a three-dimensional staircase. Hypothesis was that the subject functional ambulation performance score (FAPS) of gait, would improve while undergoing the intervention of optical illusion visual cues of a staircase in augmented reality software.

Method

Subjects

Three Icelandic Parkinsons diseased patients with severe symptoms matched controls for the study. Subjects were volunteers from nursing homes, were they reside or attend physical therapy. The homes were within or in proximity of the capital area with diagnosed PD patients. Subjects received an introductional letter and two subjects signed a written concent before agreeing to take part in the experiment. Only one subject was included in this study. One subject was ill during the time the experiment took place. Thus forth exluded from the study. One patient that signed a written concent and agreed to take part in the study, was measured four times on the GAITRite walkway system. During the intervention measurment, the augmented reality software was nonresponsive. Consequently, that subject and data was excluded from this study. Leaving one subject to participate. Subjects did not receive any form of payment for taking part in this study. There was one subject recruted for participation in this study, he has been given the pseudonym “John” in this study, respectively. John was 77 years old. Safety monitoring for anxiety was fulfilled by controlling the research settings in measuring John at a specific time of day when there was little or no disturbance in the nursing home, for testing.

Instruments and measures

This experiment was based on GAITRite electronic walkway (CIR Systems Inc., Havertown, PA) temporal and spatial measurements of gait. Including the intervention of AR software, presented in a tablet.

The GAITRite portable gait analysis system is an electronic walkway utilized to measure the timing (temporal) and two-dimensional geometric position (spatial) parameters with 13,824 pressure activated sensors. The walkway length is 457.23 cm, 90.17 cm wide and 0.63 cm in thickness.

Functional Ambulation Performance score (FAP) within the GAITRite software, is a scoring system that calculates a single score of gait, based on the ratio of step length to leg length to step time. In the nondisabled adult population, FAPS ranges from 95 to 100 points. The lower the FAP score, the lesser gait ability. The FAP score ranges from 30 to 100 points, with the lowest possible score being 30. Points are deducted from the FAP score, for the use of walking support tools (5) or assistance (5). If walking aids and devices are not taken in to account, the lowest possible score is 40 (range 40–100).

Instrument used for the intervention was an augmented reality software programmed in collaboration with the department of computer science in the Reykjavík university, by Unnar Kristjánsson MSc, Computer Science. Unnar Kristjánsson received 2 ECTS from the Project Admissions Board of University of Reykjavík for taking part in this study by building the AR software.

Unity 3D (2016) is a software development framework, designed primarily for the purposes of supporting development of video game related software. Due to a broad focus provided by a flexible set of tools, and large platform support (desktop computers, mobile devices etc.), Unity is commonly used by academics in various fields of science to aid in their research through custom software specifically developed for said purpose.

The Vuforia (2017) Augmented Reality SDK, is a software development kit, or a set of tools, aimed to support and ease the creation of Augmented Reality (AR) applications for use on mobile devices. With Vuforia building upon recent trends and principles surrounding AR fields and their use.

The development side of applications using Vuforia is supported through multiple means, including a pre-existing integration into the Unity 3D engine, allowing Unity's framework to be used in the creation of software with the AR toolset Vuforia provides. This combination of frameworks thus provides an ideal environment in which AR related software may be created and developed to support multiple different devices, and purposes, whether they be academic or recreational. The marker used to trace the AR staircase illusion was a A4 sized magazine paper (see figure 1).

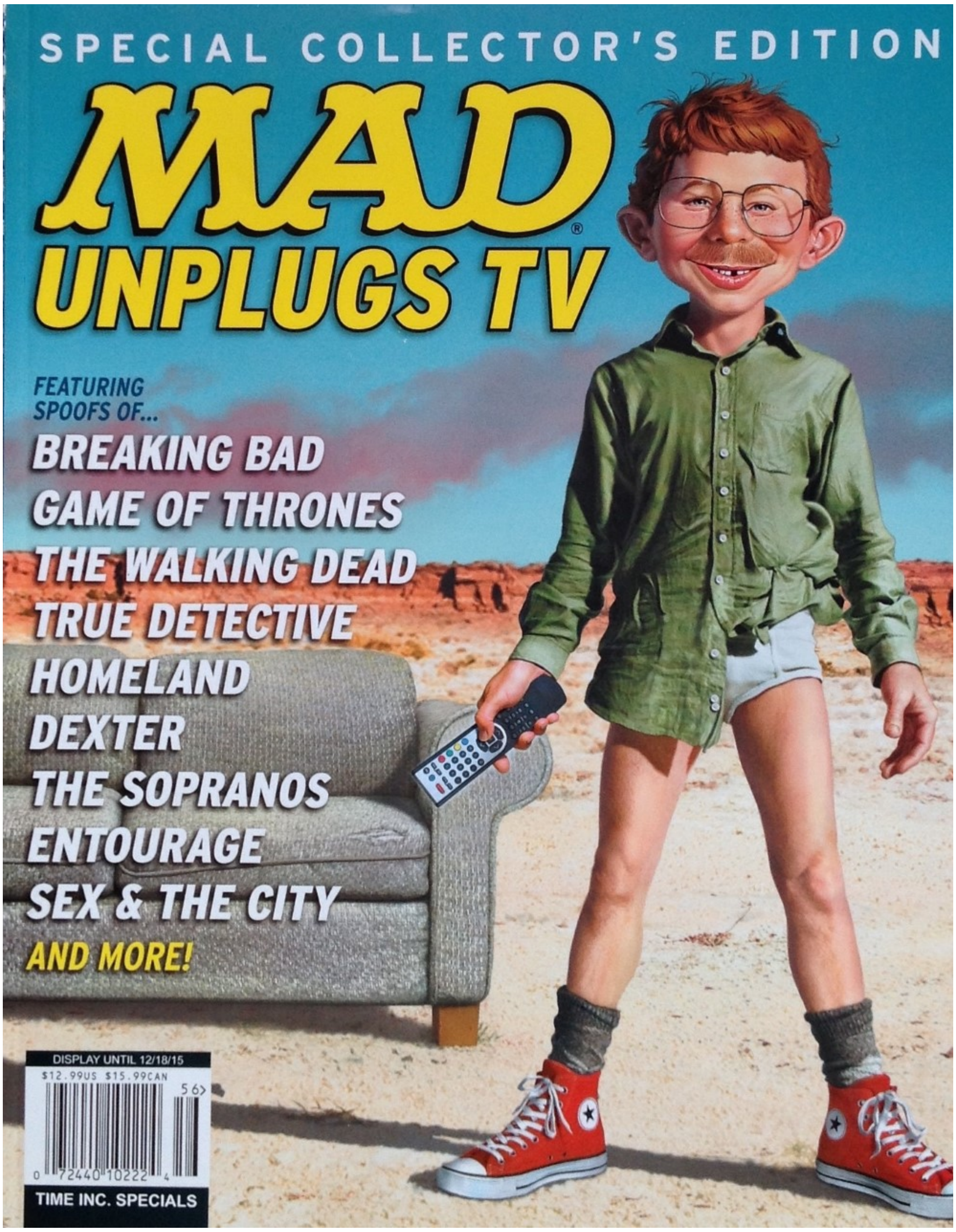

Figure 1

Marker used to trace the three-dimensional staircase through AR software

The 3-dimentional staircase illusion image (see figure 2), was collaborated by the researcher and designed by Unnar Kristjánsson, targeting the staircase illusion graphic design from Soneji (Janssen et al, 2016).

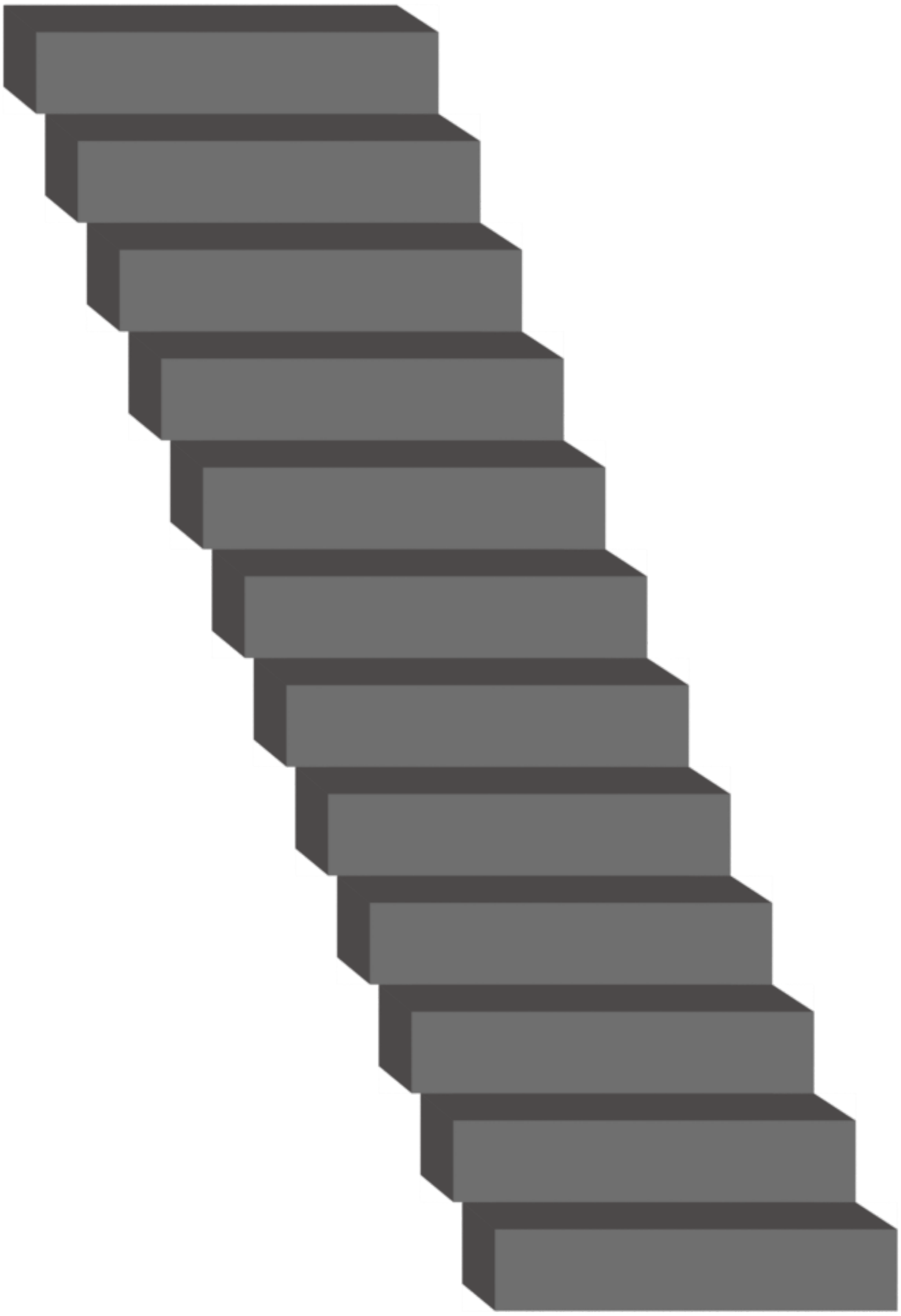

Figure 2

Three-dimensional optical illusion staircase designed for this study

Instrument used to present the AR software intervention, was an Apple iPad 3rd Gen tablet, a screen display of 19.7 cm in height and 14.7 cm in width (Apple, 2017), with a rear-mounted 5 megapixel iSight camera, 1080p video.

Research design

The experimental method of this study applied a single subject ABA baseline design, that was used to compare the baseline FAP scores of the GAITRite walkway to the intervention FAP score of AR visual cue software and reverse back to baseline.

The dependent variable in this study was the gait ability (FAP) measured and analyzed with the GAITRite walkway system. The independent variable in this study was the 3D visual cue of a designed staircase illusion presented in AR software.

Procedure

The experiment was conducted in the period of two days, the 16th and 18th of May 2017, in a nursing-home. The experiment took place in a reserved room where there were professional staff of the nursing home for assistance and oversaw the execution of the experiment. The researcher begun by placing the GAITRite walkway in a designated place, with sufficient space on the left and right side of the mat, for the staff member to walk along-side the patient to control for possible falls, and for the researcher to walk along the other side, in the intervention measurement, with the tablet. Johns gait was measured six times per day. John received the same instructions for each session of measurements that was performed in the experiment. Before the GAITRite measurements begun, the researcher measured Johns left and right leg length, from the trochanter (hip bone). Additionally, taping down the A4 sized marker on the opposite end of the GAITRite walkway mat, from the starting point of Johns walk. John was asked to begin and end his walk 100 cm before and after the walkway to reduce acceleration effects. Additionally, asked to walk across the GAITRite walkway, in his comfortable walking speed, across and back the walkway, 5 - 6 times in total. A verbal cue was provided to initiate walking. John was able to walk with any type of support tool preferred, with the exception of the intervention measurement was introduced, then the support tools were confined to a walker, walking bridge or railing if preferred.

Intervention was performed once on John. Before the intervention measurement begun, the researcher taped down the A4 sized marker on the left side, opposite end of the GAITRite walkway mat, from the starting point of Johns walk. Initial instructions were the same for intervention performed, with additional intervention related instructions. John was asked to walk back and forth across the GAITRite walkway, in his normal walking speed, three times in total. Additionally, asked to look through an iPad screen that the researcher held up in a 45-degree angle, with a clear view of the augmented reality visual cue of the staircase (see figure 2) traced on the GAITRite walkway and the marker (see figure 1) used to trace the staircase across the mat. Additionally, safety measures for falls were implemented, by having a staff member of the nursing home walk beside John in all measuring sessions.

All subjects signed an informed consent before taking part in this study and received an introductory letter, informing them their right, to withdraw consent at any given time while the study took place. This study was approved by the Icelandic institutional Bioethics Committee (no: 17-112-S1).

Analysis

Visual analysis of the results projected in a line graph. Data analysis of FAP scores was performed in the GAITRite software. Advanced foot separator, flexible midline and walker eraser was used manually, for the software to be able to process and analyze the FAP score for all walks separately.

Results

Single subject ABA baseline design was used to measure and compare the effect of the intervention on John.

Table 1 presents the descriptive criteria needed to calculate the Functional Ambulation Performance Score (FAPS), within the GAITRite software. John, a 77 year old male diagnosed with PD, was confined to a wheelchair on a daily basis. John used a walker support tool as well assistance from a staff member of the nursing home, to perform all walks across the walkway.

Table 1

Descriptive criteria for GAITRite calculation of FAP score

Sex	Age	Right LL (cm)	Left LL (cm)	Support
M	77	97	96	Walker/Assistance

Deduction points for using support tools (5) and assistance (5) was implemented in this study and reported, respectively.

Figure 1 presents FAP score data for John in the single ABA subject design.

John performed 12 walks across the GAITRite walkway in total. Baseline phase consisted of the first six walks across the walkway.

The first baseline walk produced a FAP score of 44 (see figure 3). The second baseline walk produced a FAP score of 46 The third baseline walk produced a FAP score of 37. John completed the first three walks in stable time, or 8-9 s. (see figure 4). The fourth baseline walk produced a FAP score of 45 and was completed a second later than the first three walks, 10.30 s. The subject was fatigued after the fourth walk and needed to rest in a chair for one minute. The fifth baseline walk produced the same FAP score of 45 as in the walk before the minute of rest, except the walk was completed in less time, or 7.00 s. (see figure 4). The sixth baseline walk produced a FAP score of 40 and was completed in just over 7 s. Thus, concluded the first baseline measurement. Johns baseline FAP score measurements were relatively stable (M = 52.8) after the sixth walk before the intervention was introduced in the seventh walk across the walkway (see figure 1).

The intervention was implemented in one walk across the walkway, in the sixth walk across the walkway. The intervention walk produced a low FAP score of 38 and was completed in double the amount of time needed for other walks, or 12.11 s. (see figure 3, 4). After the sixth walk, measurements ceased, due to subject fatigue.

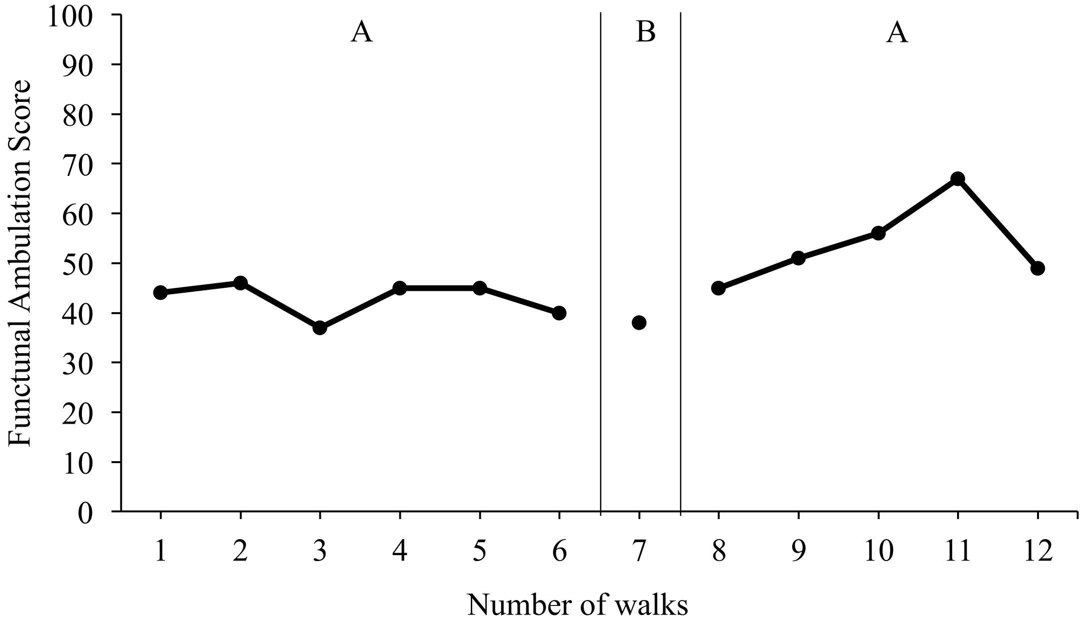

Figure 3

FAP score graph of all 12 walks made, after the deduction points (10), respectively.

Measurements on the GAITite walkway continued two days later (see figure 3). More intervention measurements were not possible due to malfunction of the intervention software. Researcher decided to move on to the reversal baseline. The first reversal baseline walk produced a FAP score of 45 and was completed in the longest time John needed to walk across the walkway or 13.39 s. The second baseline walk produced a FAP score of 51 and was completed in a relatively stable time for John or 7.29 s. The third baseline walk produced a FAP score of 56 and was completed in 6.35 s. The fourth baseline walk produced a the highest FAP score measured from John or 67 and was completed in the shortest time measured 4.78 s. The subject was fatigued after the fourth walk and needed to rest in his wheelchair for four minutes. The fifth baseline walk produced a FAP score of 49 and was completed in 6.81 s.

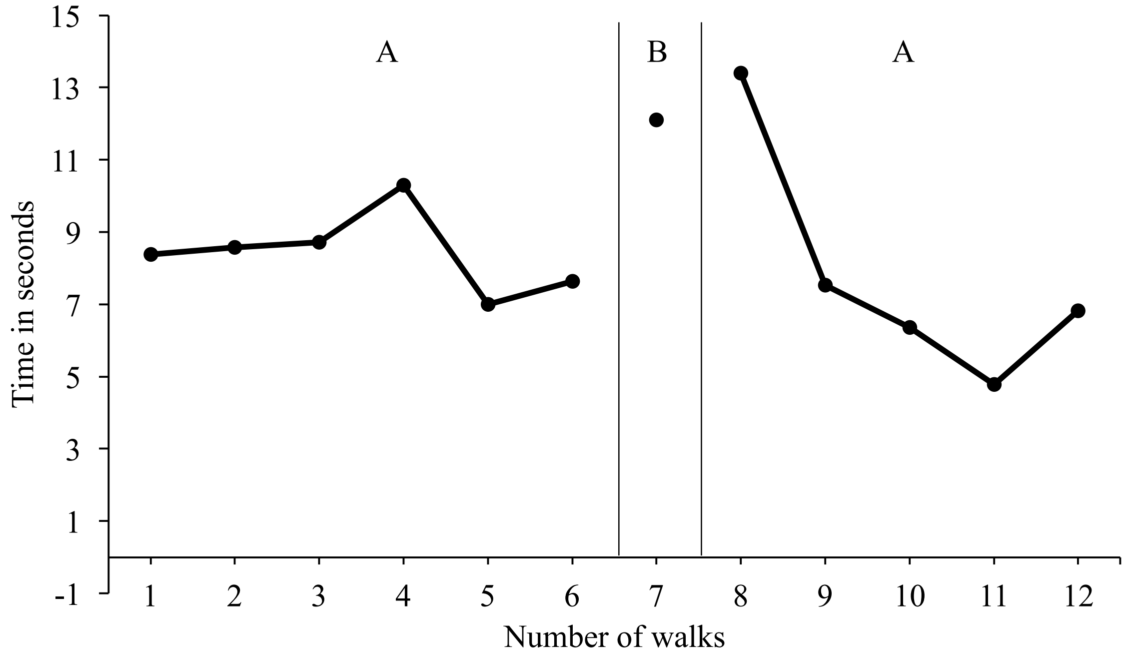

Figure 4

Graph of the time in seconds through all walks made in ABA

The second baseline walk produced a FAP score of 51 and was completed in a relatively stable time for John or 7.29 s. The third baseline walk produced a FAP score of 56 and was completed in 6.35 s. The fourth baseline walk produced a the highest FAP score measured from John or 67 and was completed in the shortest time measured 4.78 s. The subject was fatigued after the fourth walk and needed to rest in his wheelchair for four minutes. The fifth baseline walk produced a FAP score of 49 and was completed in 6.81 s.

Discussion

The results show that the intervention on PD symptoms with optical illusion visual cues in augmented reality software, presented in a tablet screen, seem to have an aversive effect on gait ability (FAP score). This contradicts previous findings of Soneji et al (2016) in a single subject study, kinesia paradoxica was stimulated with the staircase illusion graphic, in which this study was based on. They provided recorded evidence of immediate symptom relief within a severe PD symptomatic subject by stimulating kinesia paradoxica, with the staircase illusion (Janssen et al., 2016). Although, they did not present the cue in augmented reality, they provided real-life cues such as painting on floor with grayscale colours.

Nevertheless, another community based study found that by presenting virtual reality glasses with horizontal lines in a light display, decreased the number of freezing of gait for most patients (Kaminsky et al., 2007). However, in contrast to this study, they gave the participant glasses to wear for a whole week or more, for the entire day, in their home, while there was only one intervention walk measured in this study. However, another study found that real-life transverse line cue improved gait ability more than three different virtual reality cues tested (Griffin et al., 2011), except the cue of visual flow, which improved gait only moderately. Nevertheless, visual downward displacements on a staircase in full virtual reality, improved postural stability with 15 PD patients (Yelshyna et al., 2016). Again, in contrast, this study showed an augmented reality tablet screen, compared to fully immersed virtual reality world. However, augmented reality training was implemented on 42 PD patients that improved postural control (Yen et al., 2011). Training, being the key word in this context for this study only implemented one measurement of intervention, However, training was never the goal of this study, only measuring the immediate effect of visual cues that studies have reported in the foregoing argument. In consideration of the foregoing, one intervention is a large but uncontrollable shortcoming of this study using ABA design. With that being said, there are different factors that need to be addressed when dealing with such a degenerative neurological disease. There are different motor and non-motor attributes (Tanner & Goldman, 1996) that are disabling, especially with the advancement of the disease (Jancovic, 2007). Symptoms that displayed themselves in John were progressive, rigidity, tremor at rest, postural instability, flexed posture, gait disabilities and seemed to have freezing of gate. Result stated unstable gait in the reversal baseline measurement. When he begun walking, he had never had such a delay, as the measurements continue, he experienced less delays, according-to the GAITRite software. By the fourth walk he was walking across the mat in less than 5 s. and had the best FAP score he had ever gotten on the walkway system, 67(FAP). These results can be misleading, after observing him walk across the walkway with a walker and support from a staff-member, it was evident that he walked faster to finish sooner because of fatigue. In the last walk it is evident that the FAP declined and the time it took for him to walk was delayed. These could suggest that symptoms were too progressive and subject to variability concerning daily form, to measure so seldom before intervention. Additionally, attention deficit might be in place (Wolfe et al, 2009), which proves very problematic when trying to implement goal-oriented visual cues through a screen while performing another task. Working memory is the foundation of logical thought, and function in every day activities

There are number of limitations in this study to report. Original design for the study was to apply a single AB, multiple baseline design across subjects to measure and compare the effect of the intervention on three PD subjects at different time points. Three subjects volunteered from the nursing home, two subjects were measured and provided a signed consent.

The main limitation would be the time constraint the study was under, with eight days to execute the experiment, measure subjects and report results, due to a late approval from the

Icelandic institutional Bioethics Committee. Furthermore, executional limitations due to specific dates the researcher was, allowed to measure the PD patients. Those limitations consisted of only being able to measure subjects when they arrived to physical therapy session within the nursing home. This protocol was implemented by the nursing home, due to the fact, that some subjects were not inpatients, but resided within their own homes and traveled by a bus, provided by the nursing home, from their own home to receive physical therapy within the nursing home. This resulted in the exclusion of one subject, due to illness at the given dates of experimental execution. Which left two subjects to participate in the study. The second subject excluded from this study, was measured four times on the GAITRite walkway and showed a consistent baseline, with a FAP score ranging from 84 - 87 (M = 86). The subject was excluded because the augmented reality software was nonresponsive at the time of the intervention measurement. The subject was not able to return at another time, when the AG software would be responsive, for an intervention measurement because of the nursing home protocols. Protocols consisted of measuring the subject only of the time of physical therapy session, mainly because the subject was not in residential care. This left the last subject that was reported in this study, John.

The time constraint was especially limiting due to the sensitivity and small sample frame. The subject that was reported in this study, had progressive PD and confined to a wheelchair with problematic gait disabilities that required the staff member of the nursing home to supply support through all walks measured.

Additional methodological limitations concerning frequency of measurements and intervention presentation are open to criticism. The frequency of measurements on the GAITRite walkway, during the first session, consisted of six baseline measurements of FAP score points. Immediately following, the intervention measurement. This can be problematic due to the symptom sensitivity of the progressive PD, that resulted in patient fatigue during the intervention measurement. Again, this is partly due to time constraints of the study. Critique concerning the presentation of the intervention in a tablet, raises reliability issues concerning the intervention FAP score (FAP = 48) and delayed time (13.30 s.). For the procedure of tracing in the AR software was unstable, to stabilize the tracing there was a procedure of narrowing down the tablet towards the image and walking slowly and steadily away with the camera of the tablet pointed towards the marker, results in possible slow and stiff movements of the researcher performing the intervention that may have led to delayed walking time for John, but does not fully explain the low overall gait ability (FAP). Although, in good lighting, the turbulence of the tracing did not seem to be a problem.

Lighting was another issue where the intervention took place. It was not insufficient lighting, rather too much that reflected upon the screen of the tablet, due to a glass ceiling. John was asked if he could sufficiently see the image on the screen which he agreed upon. This could be a serious issue for the intervention relies on providing visual cues. Nevertheless, studies have reported simple cues such as horizontal lines on the floor do indeed provide a good stimulus for kinesia paradoxical. Just by turning a regual walking cane with a handle, proved to be successful in relefing gait disabling symptoms such as freezing of gait (Dunne, Hankey, & Edis, 1987). What proved to be more successful than a upside down walking cane (Diez, Goetz & Stebbins, 1990), were horizontal lines placed on a walking path with irregular intervals. Furthermore, gait improvement was reported with implementing step length markers as a visual cue. In contrast of the foregoing, it seems problematic why the augmented reality software in this study did not take effect.

Future studies can especially address the limitations of this study by implementing a much longer time frame for experiment execution, due to the sensitivity of the group. Take fewer measurements per session, and distribute walks over a longer period, in addition to more intervention measures. Having a larger sample would lower the risk of no results due to, again, group sensitivity and exclusion thus forth. Additionally, making sure the software is functional and implementing the staircase illusion into AG glasses rather than a screen tablet. Also, with progressive PD subjects, it is feasible to screen for attention deficit disorders or working memory capacity before implementing goal-oriented visual cues while performing a task of walking.

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