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MASTER THESIS: TOEGEPASTE COGNITIEVE PSYCHOLOGIE

Walking through apertures with Field of View Restriction

A study of locomotion and perception performed at TNO.

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Abstract:

This study investigates the effect of both horizontal and vertical field of view restriction on walking through apertures. Speed, angle of passage, the range of shoulder rotation and clearance of the aperture were used as measures. The hypothesis was that field of view restriction would increase the rotational angle by which participants passed through apertures because the perception affordance between them and the aperture would change. No effects were found on shoulder rotation nor an effect of horizontal field of view restriction was found. However, when the visible visual angle in the vertical plane decreased, walking speed decreased. Meaning that confidence is lost when the vertical Field of View is restricted, but not when the horizontal Field of View is restricted. This leads to speculation when and how people judge aperture passability. Furthermore, shows this study more evidence for affordances and an understanding as to how people pass through apertures.

Introduction

Walking through apertures

In daily life people move constantly through structured environments. This requires us to move through openings (or apertures) without colliding with them. In order to pass through apertures safely and efficiently we are required to constantly judge whether apertures allow us to walk through without rotating our shoulders or whether we have to make adjustments such as shoulder rotations for an aperture to be passable. It is a question of whether an aperture affords a person to pass through. These affordances were defined by Gibson (1979) as the actions an object affords or allows to an organism with certain action capabilities. Therefore, it is always an interaction between person and environment.

A participant does not judge aperture size and passability based on metric data, but in relation to the body itself. The properties of the aperture (opening width) and body measurements (body width, mostly measured in shoulder width) in relationship to each other allows a person to pass through with or without rotation. Warren and Whang (1987) found that at an aperture-width ratio of 1.3 times the shoulder width participants consistently start rotating their shoulders before passing through the aperture; participants apparently use a small safety margin in judging an aperture as passable. In a second experiment they instructed the participants to give a verbal judgment whether they could pass through an aperture without turning their shoulders. They conducted both a static condition and a moving condition. Their results showed that when the data was scaled intrinsically (meaning based on their own body measurements) the aperture-width ratio by which a participant judged an aperture as passable was similar between broad and narrow shouldered participants. They conducted a third experiment where they manipulated the eye-height of participants using a false floor. From the obtained results they concluded that participants are aware of their eye-height from the floor and use this information to judge distance and aperture width quite accurately. This was also found by Wu et al (2004) he also indicated that local ground area is integrated in a global reference frame. In normal vision, static monocular information appears to be sufficient for consistent judgment of passability regardless of body size (Warren and Whang 1987).

How robust this ratio from aperture to shoulder is is shown by Higuchi et al (2006) who found that even when the body dimensions of participants are artificially altered they still move fairly accurate when passing through apertures. For this experiment participants had to pass through apertures whilst having limitations that made them broader such as a wheelchair or a horizontal bar held at hip height. Only when shoulder rotation was restricted the participants were found to be more error prone. Other evidence for adaptation to different body dimensions was found by Hirose & Nishio (2001) and Ishak, Adolph & Lin (2008).

Wagman and Malek (2007) argue that the accuracy of verbal passability was dependent on the speed at which participants anticipated walking through an aperture while carrying different objects. In the first condition participants were not allowed to see the objects they were holding and in the second one they were only allowed to see the object but not treat it haptically. The participants had to estimate whether they could pass through an aperture while running or while walking in both conditions. The participants felt less secure about their judgments when the objects could only be held and not seen; though their judgments did not differ in accuracy when compared to the condition where they could see the object and not hold it. However, when participants were asked whether they could run through an aperture with a broad object, then their estimates were far more conservative in both the haptic and visual condition.

Furthermore, Lopresti-Goodman et al (2010) found that in men heightened body awareness caused them to walk with less shoulder rotation through smaller apertures compared to the condition with lower body awareness. In women no such change was found. In other words heightened body awareness in men caused a decrease in the aperture to shoulder width ratio, thus the perception of affordances to change. The shift in perception of affordances is even more highlighted by Chang et al (2009), who report that one participant can correctly estimate aperture widths in passability when passing through with two people simultaneously (usually in an adult-child dyad), meaning that the estimation of ones own proportions can be altered, thus the perceptions of what can be afforded change. Moreover, practice can lead to more accuracy in aperture passability judgment (Ishak et al 2008; Higuchi et al, 2006)

Field of View Restriction and Walking through apertures

There are several ways in which the field of view (FoV) of a person can be limited. In daily life we find such occurrences when carrying large objects when our feet are out of view. Wearing caps or hoods will block our peripheral vision. Persons wearing glasses will find their peripheral vision both horizontally and vertically diminished. While training or rehearsing in a virtual environment head-mounted displays (HMDs) are frequently used. Werner (1991) describes that unrestricted the human FoV is about 200° horizontally and 135° vertically. In most common HMDs the viewing angle is limited to 40-70° and 50° respectively. Because FoV restriction is so very often encountered and larger HMD's are costly it is important to understand the effects of these restrictions on locomotion through structured environments.

FoV restriction affects distance estimation (cf., Patla, 1998), postural equilibrium and the ability to control heading (e.g., Gibson, 1958; Amblard & Carblanc, 1980; Paulus *et* al., 1984). However, to what extent field of view restriction has an influence when walking through apertures has not been researched yet. Research in other areas of human locomotion suggests that FoV restriction would influence aperture passage. When avoiding obstacles it has been found that FoV restriction alters movement patterns of participants. For example, Rietdyk & Rhea (2006) found that when stepping over objects, toe clearance increased when the FoV was restricted. Even when the participants received other position cues of the object they had to cross, the trail limb clearance was larger in the FoV restricted conditions than in the full-view conditions. In addition, Jansen et al (2011) showed that with an intermediate vertical viewing angle toe clearance and step length increased when having to step over an obstacle but speed remained unaffected. However, in the conditions where the largest restrictions on FoV were put (giving the participants only a viewing angle of about 25 degrees), speed decreased. Toet et al (2007) found that when participants had to steer through an environment in an S-curve, bortj walking speed and accuracy decreased with decreasing FoV.

In another experiment by Jansen et al (2010) they segregated the horizontal and vertical viewing angle to see how it would affect manoeuvring performance. The participants had to traverse three different kind of obstacles: three bars of different heights which they had to step over, a set of three walls which required the participants to steer in an S-curve and a low hanging bar which they had to pass underneath. They found an increase in time in traversing the course because the participants kept a larger clearance throughout the apparatus. Vertical FoV restriction increased head movements whereas horizontal restriction did not. Vertical FoV restriction affects ground surface integration (Wu et al, 2004; Creem-Regehr et al, 2005). This might influence distance and aperture width judgments. Horizontal FoV restriction restricts the optic flow when moving towards an object, which might impair heading accuracy (Gibson, 1958). When close by the aperture opening, the edges will fall out of sight. This might decrease accuracy and confidence when passing through an aperture, thus will cause an increase in the clearance as a safety precaution.

Field of view restriction in apertures in the current study.

Previous work done on the relation between Fov restriction and obstacle avoidance suggests that FoV restriction might also influence walking through apertures. However this has not been shown yet. In order for that to be clear our main question will be whether FoV restriction influences the aperture to shoulder ratio when passing through an aperture. We hypothesise that restriction of the visual field will cause an increase of the aperture-to-shoulder ratio. Meaning that with smaller FoV's the participants will start rotating at larger apertures. This we assume because the perception of one's own body and the environment would change due to FoV restriction. With this change, the perception of what an aperture affords would shift as well. Another hypothesis is that, consistent with the results of Jansen *et* al. (2010), the clearance between aperture and shoulder will increase, due to the horizontal FoV restriction which impairs balance performance.

The latter will be measured by the distance between the aperture edge and the shoulder of the participant. We hypothesise that there will be a larger clearance from the aperture than when there is no FoV restriction. How this clearance is achieved will also be researched by measuring rotation speed and maximum rotation angle. Furthermore walking speed will be used as a measurement of confidence, based on the assumption that when people are less confident, their speed will decrease.

We will also separate horizontal and vertical FoV restrictions in order to answer what different effects horizontal and vertical FoV restriction have on walking through apertures. The aperture widths are based on individual shoulder widths, and the FoV reduction was achieved using goggles taped to limit the view to smaller angles.

To summarise our hypotheses:

- A decrease of the visual field will decrease the speed by which a person passes through an aperture.
- A decrease of the visual field will cause an increase of the aperture-to-shoulder ratio.
- A decrease of the visual field will increase the angle of passing through an aperture.
- A decrease of the visual field will increase the clearance between shoulder and aperture

Methods and materials

Participants

9 participants took part in the experiment of which 3 were male and 6 were female. The participants had an average age of 35.1 years with a standard deviation of 17.4 years. The participants were divided into two groups: one group with lengths ranging from 1.55 m to 1.65 m and a weight-range from 50 kg to 65 kg and a second group with lengths ranging from 1.80 m to 1.95 m and weights ranging from 85 kg to 95 kg. This division was made to accommodate the two available motion capture suits in the sizes small and extra large. The participants were recruited from the TNO participant database. The participants all gave an informed consent and were free of any known orthopedic or neurologic disorders, verified by self report. All participants had normal (20/20) or corrected to normal vision. The participants received payment in return for their participation.

Apparatus

Sixteen pairs of safety goggles were used (type Bollé Targa: www.bolle-safety.com) one for each viewing condition. The FoV was restricted by covering parts of the goggle lenses with duct-tape. In total there were four horizontal and four vertical restrictive conditions. The horizontal viewing angles were of approximately 40°, 80°, 115° and 200° and the vertical viewing angles were approximately 25°, 40°, 60° and 135°. However, these angles could fluctuate depending on the facial shapes of the participants and therefore will in the rest of this paper be referred to as small, medium, large and full. Each combination of horizontal and vertical angle was used. The goggle legs could be adjusted so that the goggle openings fell directly in front of the participants' eyes (see fig. 1).

Figure 1. An example of the goggles worn together with a forage cap and the wordviz leds (However, this photograph is without the xsens motion capture suit). On the right all different goggles are displayed.

Apertures.

The participants had to traverse a six meter long path at which the apertures were placed at 5 meters. The apertures were created by making use of two grey walls (with dimensions of… of which the left one remained stationary and the right one was moved by the experimenter to create different sizes of apertures. At 1.5 meter behind the aperture a similar wall was placed in order to remove any distractions (see fig. 1). After each trial, the participants walked back along the outside of the course. They were instructed to walk at their preferred speed through the apertures. It was not specified in what manner the participants had to walk through the apertures. The size of the openings was determined by the shoulder widths of the participants; namely 1.1, 1.2, 1.3, 1.4 and 1.5 times the participants shoulder width.

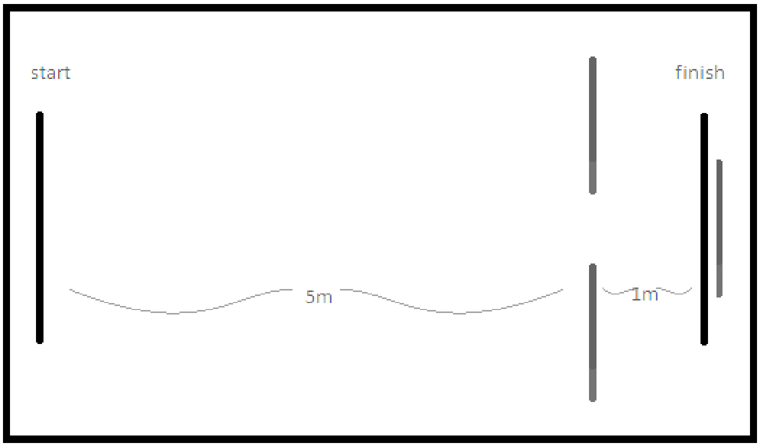

Figure 2. Schematic depiction of the obstacle course.

Motion capture

Two systems were used to capture the locomotion of the participants: the optical PPT motion tracking system from Worldviz (www.worldviz.com, Santa Barbara, USA) (in which PPT stands for precision position tracking) and the inertial motion capture system Moven studios from XSens (www.xsens.com, Enschede, the Netherlands). In this study only the data of the Worldviz system was used, but in future studies the data generated by the motion capture suite can be used to attain other kinematic measures such as step width and head pitch.
Worldviz makes use of 4 cameras to determine the position of a small led-light with a rate of 60 Hz. We placed a marker on each shoulder of the participant and a third on the left wall to measure the shoulder clearance. The participants wore a lycra suit which contained 17 sensors, which held gyroscopes, accelerometers, and magnetometers. The full body motion of participants was recorded with a rate of 120 Hz.

Video registration

Four surveillance cameras recorded the whole experiment. They were turned on when the participants entered the laboratory and turned off when they left. Two cameras overviewed different parts of the track and one camera overviewed the full experimental area. The fourth was used to identify participants, in later viewings if necessary. The videos were used to observe what actions participants had performed when we found our data to be irregular from normal (This could be longer trials, or a deviating number of trials) and to observe certain qualitative aspects of manoeuvring through apertures.

Procedure and Design

The experiment was a 4 (vertical angle) * 4 (horizontal angle) * 5 (aperture width) within participant design. In addition, an unrestricted (without goggles and with the aperture opening set at 1 meter) condition preceded the experiment. Each condition consisted of 4 trials resulting in 324 trials in total for each participant. The conditions were presented in a random order which was created using a list of randomly numbers generated in excel.

After filling out the informed consent form participants put on the Lycra motion capture suit. Before the experiment started, the height and shoulder width of the participants were measured. These measurements were used to determine the aperture widths. After that the optical-markers were placed on the participants shoulder. Before each condition the participant was instructed to put on a specific pair of goggles while facing away from the course. At this moment the aperture size was adjusted. The participants were then instructed to stand tip-toe at the beginning and end of the course. This was done to create a definite starting point from which the data would be analysed. For each condition the path was traversed 4 times, after that the participants were instructed which pair of goggles to wear next.

The participants were instructed not to touch the walls while walking through the aperture, but not as to how to walk through them. The latter was done to stimulate a type of walking that is the closest to natural behaviour. There was the possibility of a short break at the 30th and 60th condition during which the participants were allowed to sit and have something to drink.

Data analysis

In total four measurements were examined. First, we determined the normalised speed by which a person passed through an aperture. That is, the speed was calculated at each frame over a distance of 4.5 meters before the aperture until the point of passage of each trial. Subsequently, the averaged speed per trial was normalised to the preferred speed found in the pre-test. Second, the normalised range of shoulder rotation was measured, which was as the largest angle between the two shoulders during each trial. Thereto, the largest angle between each shoulder marker was determined and normalised to the preferred range found in the pre-test. Finally, the angle by which participants pass through an aperture and the clearance between shoulder and aperture were used as measurements. The pass angle is the absolute angle difference between aperture and person at the moment of passing. The moment of passing was defined as mid person crossing mid-aperture. The clearance was measured by taking per trial the smallest distance of either the left or right marker, from the wall as a percentage of the aperture opening.

For each condition the three last trials were used in analysis, unless there was missing data, in which case the data from the first trial were taken into analysis.

A 4*4*5 repeated measures analysis of variance (ANOVA) was used for each of the dependent measures. Whenever Mauchley's test indicated a violation of sphericity a Greenhause-Geisser correction was applied on the analysis of variance as well as a Bonferroni adjustment on the pair wise comparisons. The significance levels were set at 5%.

Furthermore pearson's coreelation was performed on the different measures, this to check whether the measurements measures the same characteristics

Results

Our study demonstrated that participants move fairly accurate through apertures, even with quite severe FoV restrictions.

Speed

An effect of vertical FoV restriction on normalised speed was found ($F(3,24)=6.977$ and $p<0.005$). When the vertical angle was restricted participants walked more slowly. The post-hoc analysis shows that the smallest vertical angle differs significantly with the full, large and medium vertical angles with $p= <0.005$, $p=<0.05$ and $p<0.05$ respectively (see fig. 3).

No effects of horizontal FoV restriction were found for speed.

Aperture width had a significant effect on normalised speed ($F(4,32)=12.7$ and $p<0.001$). When the aperture got smaller participants walked more slowly. The post hoc tests show that the smallest apertures size (1.1 times the shoulder width) differs from all other aperture sizes. ($p> 0.05$, $p>0.005$, $p>0.001$ and $p>0.001$) and the second smallest aperture width (1.2) differs significantly from the larges aperture(1.5) ($p>0.05$) (see fig. 3).

Furthermore an effect of trial was found in normalised speed ($F(2,16)=7.9775$, $p<0.005$). Each condition had four trials of which the last three were analysed. In the last trial participants walked slower than in the first trial.

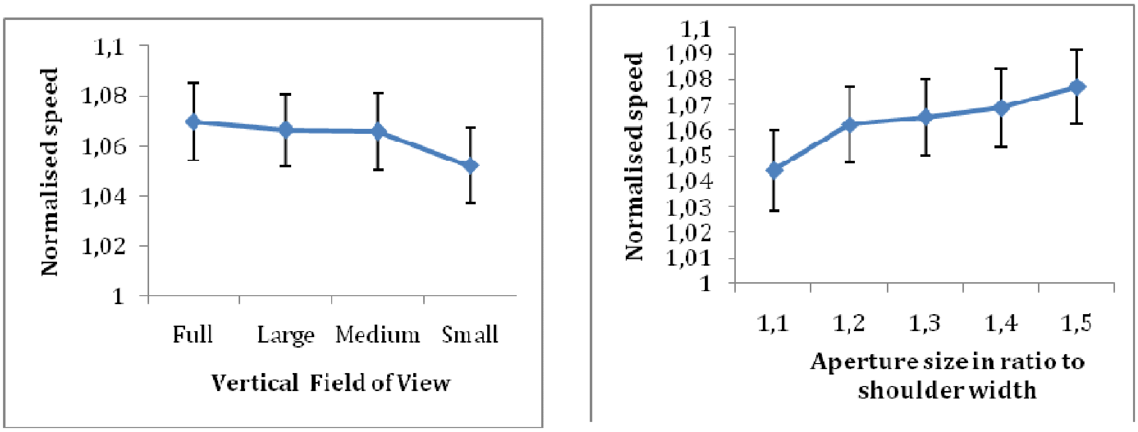

Figure 3. The left panel displays normalised speed against the vertical FoV, in which the smallest FoV differs significantly from the rest. The error bars are the standard error. The RIGHT panel shows the aperture size (in ratio to shoulder width) against the normalised speed. The error bars display the standard error in which very little deviation was found.

Normalised Range

For normalised range a significant effect for aperture was found ($F(4,32)=13.447$ and $p<0.001$). The shoulder rotational range was larger when the apertures were smaller. Aperture 1.1 differed significantly from the apertures 1.3, 1.4 and 1.5 ($p>0.001$, $p>0.001$ and $p>0.001$). Aperture 1.2 differed significantly from the apertures 1.4 and 1.5 ($p> 0.05$ and $p<0.001$; see fig. 4).

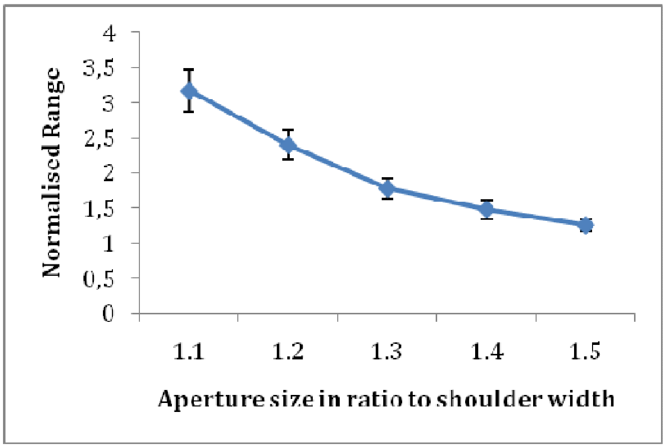

Figure 4. This figure displays the aperture size is set against the normalised range in which the error bars display the standard error.

Angle of passage

For angle of passage a significant effect for aperture was found (*F(4,32)=11.427* and *p<0.001)* when the size of the apertures decreased the rotational angle of the shoulder increased. The angle of passage at an aperture of 1.1 differed significantly from the passage angles at apertures 1.3, 1.4 and 1.5 (*p>0.001, p>0.001* and *p>0.001).* Aperture 1.2 differed significantly from the aperture 1.5 (*p> 0.05)* (see fig. 5).

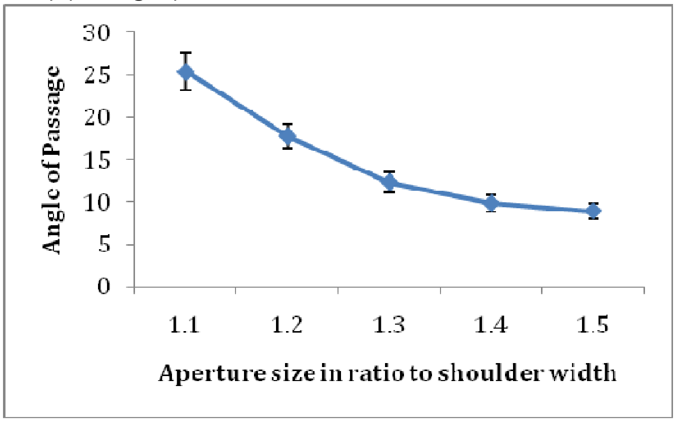

Figure 5. In this figure the aperture size is set against the angle of passage in which the error bars display the standard error.

Clearance

For clearance a significant effect for aperture was found (*F(4,32)=16.518* and *p<0.001).* When the aperture size decreased so did the clearance. Aperture 1.1 differed significantly from the apertures 1.4 and 1.5 (*p>0.001* and *p>0.001).* Aperture 1.2 differed significantly from the apertures 1.4 and 1.5 (*p> 0.005* and *p>0.001).* Aperture 1.3 differed significantly from the aperture 1.5 (*p> 0.005;* see fig. 6).

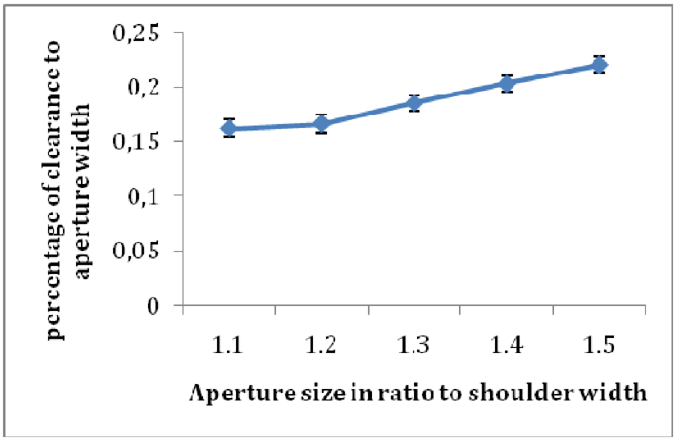

Figure 6. This figure displays the aperture size is set against the clearance in which the error bars display the standard error.

Correlation between measures

The measures have all been found to significantly correlate amongst each other at an alpha of 0,05. These correlations can be found in table 1. The largest correlation can be seen between pass angle and range (*R=0,617* and R^2*= 0,38*). Using Cohen's guidelines for correlation this can be defined as a strong correlation (R> 0,5). Therefore, range and angle of passage will not be treated as different items in the discussion.

	Speed	**range**	**pass angle**	**clearance**
Speed	1	0,002704	0,070756	0,152881
Range	0,002704	1	0,380689	0,009801
pass angle	0,070756	0,380689	1	0,002809
clearance	0,152881	0,009801	0,002809	1

Table 1. Explained variance (R^2) between measures, all correlation are significant at an alpha of 0,05.

Conclusion and discussion

The main findings in this study demonstrate that even with fairly large FoV restrictions, passing through apertures still is quite accurate and that not many changes in shoulder rotation are made to compensate. It only seems to have an effect on walking speed. The results are discussed in detail below.

FoV restriction and walking Speed

This study showed that vertical FoV restriction has an effect on the speed with which people approach and pass through apertures. At the smallest vertical visual angles the speed was smaller than in the larger vertical visual angles (see fig 3). This is consistent with the findings by Jansen et al (2011) who found that when vertical view was restricted a little, there was no effect on speed, but when the restriction was large enough speed was sacrificed for safety, a similar pattern is found in the present study. We see that the pattern is not necessarily a linear effect, but rather a plateau, after which the speed suddenly drops. This suggests that there is a shift in strategy. Speed will be preserved through limitations for efficiency, but after a certain critical cut-off point, speed will be sacrificed for safety. In the present study the participants experienced a very structured environment and had to walk the same path over 320 times, thus got very familiar with the course. The participants could walk at a speed they found comfortable. However, in this relatively safe environment a decrease in walking speed still took place. An interesting follow up question would be whether participants decrease in speed sooner in more unpredictable environments when their FoV is restricted.

Interestingly no effect of horizontal restriction was found on speed. The participants were free to move their head in any way they wanted to compensate for their visual handicap. This means that the head could be turned sideways to keep the edges of the aperture in view even at the smallest visual horizontal angles (which were angles of about 40° whilst the full horizontal viewing angle is approximately 200°). Apparently this compensation yields enough certainty for passing through no adjustment of speed in necessary. With horizontal restriction participants needn't turn their heads away from their goal (i.e., the other side of the aperture). To compensate for loss of vertical view participants needed to bend their head more down to judge distance, thus look away from the aperture. This can cause uncertainty for the participants, and to compensate they will choose to sacrifice speed. Slowing down in speed will provide more time in which participants can make decisions and also the impact of collision is smaller when the velocity is lower.

Hence, speed seems to be closely related to certainty and vice versa. For example, when the instruction is to run through an aperture, participants feel less secure about their judgments about passability of an aperture (Wagman and Malek 2007). It is likely that there is an accuracy/efficiency trade off in that when participants are forced to increase in speed certainty drops, and when participants are forced in an uncertain situation (though vertical FoV restriction) speed drops.

Field of View restriction and shoulder rotation

Counter intuitive and also contrary to our hypotheses, no effect of FoV restriction was found on angle of passage or shoulder rotation range. At the starting point participants were able to see the full aperture, even at the smallest visual fields. Participants are able to accurately judge from a distance whether an aperture is passable (Warren and Whang 1987). It is possible that these judgments of passability and adaptation necessary for passing are made long before the actual moment passing though the aperture. This is in concordance with findings done by Patla (1998) that visual information is processed before movements take place. This processing would be done in the approach phase when the aperture is still fully visible and then the handicap provided by FoV restriction causes no alteration in shoulder rotation. The only compensation made for this handicap is a decrease of speed. Participants choose not to generate more internal movements when safety of passage is threatened, but rather sacrifice velocity. Interestingly, in verbal reports given by the participants the horizontal restriction was described as being more of a nuisance in causing "dizziness".

Apertures and shoulder rotation

In shoulder rotation range and clearance an effect of aperture was found. When the apertures were smaller there was a larger rotational angle of the shoulder. This result is entirely expected, however the ratio at which this happens differs from the standing known ratio. Warren and Whang reported an aperture to shoulder ratio of 1.3, in this study the difference seemed to be closer to a ratio of 1.2. This is similar to ratio's found by Lopresti-Goodman et al (2010) who described that heightened body awareness in men decreased the aperture to shoulder ratio's by which they started rotating. Women in general had a lower ratio. In the study by Warren and Whang only men were participants. Also in the present study all participants wore a lycra skin-tight suit for motion capturing purposes. The method used by Lopresti-Goodman to create more body awareness was a skin-tight suit. Our data displays a similar effect.
In our video observations it was also seen that not everybody used the same technique to pass through apertures. In our experiment all apertures were passable, but some would be considered small or narrow, causing our participants to adapt to pass through. We gave no instruction on how to pass through, as we wanted to achieve a way of walking that was as close to reality as possible in such a sterile environment. We observed that most participants did indeed rotate their shoulders to compensate for the narrowness of the aperture, but some (especially smaller women) had different techniques to pass through apertures, for example by squeezing in their shoulders. This technique allowed them to pass through the smallest apertures in a straight way without having to turn their heads, thus eliminating some of the problem that visual restriction caused them. Due to the limited amount of participants no tests can be done to test this hypothesis. However, for future research it remains an interesting question whether aside from a heightened body awareness, women, more than men might have different strategies for passing through apertures or that these different strategies are caused by FoV restriction as a means of adapting to their imposed handicap.

Clearance in passing through and Steering

Our data showed a decrease in percentage of clearance when the apertures got smaller. This was expected because the space to manoeuvre through got smaller. However, as this was measured as a percentage, it would be expected to stay the same in the assumption that participants compensate to keep a similar sense of safety. However they do not compensate equally to the decrease of aperture size. Jansen et al (2011) showed that when participants had to steer through an S-curve, as visual limitations increased, so did the clearance. However when passing through apertures we find no such increase. This indicates that steering and passing through an opening could be different movements and participants use different techniques to compensate for similar handicaps.

Fatigue effects

Finally, it was found that participants decreased in speed over trials. This effect could be explained by fatigue or boredom. Interestingly the overall walking speed in the experiment was higher than the speed found in the pre-test. This could be explained by an eagerness to perform in the experiment or in the beginning of each condition, and then a decrease in walking speed, back to the preferred walking speed.

Overall this study displays a consisted pattern with the literature and lays down further evidence for the use of affordances in which environments are estimated. A very consisted ratio was found, which seems to be a close fit to the patterns found by Warren and Whang (1987). Furthermore, this study brings some interesting new insights to people's the way people respond to FoV restrictions. Vertical restrictions seem to be the most limiting for participants and cause them to be less certain. Participants are able to estimate apertures and rotational angle necessary from a distance, so FoV restriction is not a major handicap when the apertures are approached from a distance, it remains unknown what effect FoV restriction has on walking through unexpected apertures in a moving environment.

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Extras

What I've learned

Writing a thesis is essentially an educational experience, whether the final product is something you can publish or after months of work proves to be nothing but nonsense is secondary. The final paper is representative of the work delivered, but still I felt that it is an inaccurate picture of the work performed throughout the last five months. This is why the choice fell to writing a short essay on what I've essentially learned and done in the last period of my master. This period has shaped me, fogged some believes up, created new opportunities, learned to play with different systems outside of a university setting and has taught me what doing research is about.

Like mentioned before to me the final product of a thesis only comes across as a small part of the effort performed. It is a clean, dusted, neat description of your study which omits the slip ups you make, the thought processes, the struggle you have with limited data or options in your environment or the energy that's been put into it. This is a trap set immediately when you start out studying the literature. Everything you read is simple, brilliant and has interesting result. You are not aware of how many failed pilots there have been, how many ideas have been shot, or the amount of work it took. Thus you start out your research full of naïve hope that something similar will pass for you, and you learn you are wrong, and that there are a lot of twists and turns you never could have thought of yourself. However one of the most important things I've learned is that writing a paper is about making choices. You have to prune your options in order to get the clearest story. In my thesis I faced this choice twice. The first time when I decided to use the data of only one of the systems I had taught myself to use.

At TNO I had the opportunity to teach myself how to use different motion capture systems. This was fun, new and exciting. This especially counts for the Xsens motion capture suit, which creates a digital figure that in real-time digitally displays the person wearing it. This was great fun to do. To familiarize myself with the system I recorded myself dancing (which is one of my biggest passions outside of research) and started programming some calculations in MATLAB (another system I had to familiarize myself with during the process, for this Google has been my biggest friend) for example, I found out the when I do pirouettes there is a maximum of ten degrees angle difference between my neck and pelvis. Discoveries like this excited me a lot. Human balance and locomotion seem like such accurate systems and this suit has the possibility to provide a lot of insight into them. It generates so much data that it was quite difficult to decide what data to use. However, when the final measures were chosen it became clear that this data was all in excess. The simpler system could accurately provide the data necessary to get the answers I wanted. Which brings us to another important lesson I've learned: when same solution can be achieved in a simple and a complicated option, choose the simple one. This allows much clearer answers and room for less mistakes. Still, in my hope, I did use the motion capture suit, since I was doing the experiment anyways, and you never know if you have time left, what additional measures could contribute to your ideas. Eventually I got quite adept at connecting the suit, putting it together and measuring with it. This showed when eventually I could help a little with students from the VU of Amsterdam. It felt like I had acquired a skill. Alas, in the end, my time turned out to be limited and nothing of the motion capture suit made it into my paper.

The second pruning choice I had to make, when I had to take out half of my participants. This was a much harder choice to make, it was not for the time limit I made this choice, but after weeks of trying to get my program robust for the analysis of their data it simply seemed not to be possible. This separation between the two sets of participants was caused by the amount of led lights I had used. In the first half of my participants I used three led lights (one on each shoulder and one on the wall), and in the second half two (one on each shoulder). The analysis of the second group went perfectly, but with the first group something happened I couldn't take into account. Switching of the markers. The data seemed to turn around the markers, and sometimes the optical system during trials couldn't find a wall marker at all. For a couple of weeks I spend time trying to clear up my data, nearly adapting my script for each individual participants, until I seemed to have adapted and changed my script so much, I could barely recognize my original script (However, during this time I learned more programming than I did before). In the end however, the data still had too many outliers and odd bends and that time was against that for clarity I decided to ditch the group entirely. This was done under the assumption, that the first and latter group didn't differ significantly, and that the blame lay simply on the measuring system. It was a tough choice to make, because it felt like throwing away weeks of work and hours spend by my participants, but I did not want to create artificial data, because I had spend so much time adapting it.

After these choices my paper came together fairly quickly, but it still felt like a loss. Was my work enough? Were the answers to my hypothesis satisfying enough? Eventually the decision was yes, I've learned these choices are probably the most important things of doing accurate science. You have to be aware of what you are measuring and what you want to know, and get rid of what is in excess. If you don't, your results will prove worthless, because you never know what you are saying makes any sense.

Another thing I've learned, but on a far more personal level, is that I am probably not fit to be a scientist. My motivation rose when I could bounce of ideas to someone else or contribute to a group project, and the path of a phd student seems to be one too lonely for me. My solutions and ideas come quickest, when I'm actively talking and brainstorming with someone else. I prefer to work in a team-based environment, and this probably was the most valuable lessons of all.

So in the end, what can I say that I've acquired over the past half year? I've acquired a lot of skills, (MATLAB, motion capture systems, setting up research, spotting problems and possibilities for answers), I've acquired a lot of thoughts and ideas on what accurate science is and the processes that go behind it, and I've learned what I want right now on a personal level and what I'm fit to do. In the end, it was for me a very successful period.