



**KTH Computer Science
and Communication**

Effects of synthetic characters' pace on stress perception

Group 26



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Abstract

This paper investigates the potential correlation between the perception of stress and the exposure to a fast paced moving crowd in a virtual environment. After analysis of the data, with responses to a questionnaire together with measured heart rate, this study indicates that there is a correlation between the pace of a moving crowd and the perceived stress of the observer. These results however seem to be individual based on the participant. The study shows no indication of a correlation between the heart rate and the pacing of a moving crowd in a virtual environment. Due to the amount of participants in this study no general conclusions can be drawn, however the results show that there is more to be discovered upon further research.

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1. Introduction

1.1 Background

Recent studies have found that people are walking 10% faster now than in 1990 (Wiseman, 2006), whereas people living in denser populated cities generally have a faster walking pace. Meanwhile, the stress levels of these cities are increasing - a result which Withings Health Institute believes to be partly because of longer daily commuting times (Chieh, 2015).

But could there also be a correlation between perceived stress and a crowd's movement, so that people are actually promoting stress by simply walking? And can this phenomenon be recreated using a virtual crowd?

This study investigates how the pace of a crowd affects an observer in a virtual environment, with a focus on stress. In doing so, we hope to see how an individual perceives, and is affected by, other human beings and if this perception is rooted in a basic instinct that can be recreated in settings outside reality. Additionally, very few studies seem to have been done on the specific impact from a background crowd, even though this kind of knowledge could potentially help in improving urban areas where stress is prevalent.

1.2 Definition of Stress

It is difficult to give a clear definition of what stress is. According to a study by George Fink, definitions varied in the extent to which they emphasized the responses of the individuals, or the situations that was the cause of the behavior (Fink, 2012). There are different definitions depending on the situation, for example exercise or threats heighten blood pressure. It is a process where there is an imbalance between environmental demands and response capabilities for an individual (Evans, 1986).

Hans Selye has a similar definition, saying that "Stress is the nonspecific response of the body to any demand", meaning that stress has different meanings for different individuals during different conditions (Fink, 2012).

1.3 Research Questions

The defined research questions that this study aims to answer are:

- How is a static individual affected by a moving virtual crowd in terms of stress?
- Can an individual's perception of a real crowd be replicated by a virtual crowd?

1.4 Hypothesis

An individual's walking speed is often strongly correlated to their feeling of stress, where more stress often result in a faster walk (Chieh, 2015). If the movement of a crowd is slower than the movement of an individual, it could also add to the stress level as the person is not allowed to

walk in the preferred pace. This is however applicable to a person within the crowd, whereas the question this study aims to examine is how the individual outside of the crowd is affected. As such, there is a possibility that the individual instead perceives the crowd as a separate moving object, which may lead to a different result. Since common perception dictates that movement captures attention (Goldstein et al, 2013), it is our theory that a faster pace will lead to a stronger reaction in the observer, and potentially cause a stronger feeling of stress.

1.5 Delimitations

Because of time limits we have chosen to focus on external perception of a moving crowd, and will not go further into researching the response when moving within the crowd itself.

2. Method

2.1 Participants

All of the participants were students from KTH Royal Institute of Technology. There were 9 participants in total, all between the age of 20 and 24 years old. They were given biscuits and elderflower juice for participating in the study.

2.2 Apparatus and materials

During the experiment a pen, questionnaire paper, a laptop with a 15" screen, headphones, VLC media player version 2.2.4, a Wahoo Tickr Heart Rate monitor and an iPad were used. Each visual stimulus was created using Unity 5.4.0, and recorded using Open Broadcaster Software v0.659b. The experiments were conducted in seminar rooms and dining areas at Campus after classes and lunch period, to provide a quiet environment.

2.3 Stimuli

The stimuli used were three videos with a resolution of 1920 by 1080 pixels, an average bitrate of 36.37 Mbps, a frame rate of 60 frames per second, and stereo audio with an average bitrate of 192 kbps and a sampling rate of 48.0 KHz.

The visual stimuli presented during the experiments all included walking mannequins in a familiar environment to the participants, as viewed by a stationary virtual camera. The auditory stimuli was in the form of background noise from a public setting.

With the normal paced simulation as baseline, the ratio of walking speeds for the mannequins were 0.5 for "Slow", 1.0 for "Normal" and 1.1 for "Fast"; the ratio for the speed of which the walking cycle animation was played at was 0.833 for "Slow", 1.00 for "Normal" and 1.125 for "Fast". A variability of $\pm 10\%$ for the walking speeds and animation speeds was introduced in order to make the simulation feel more natural.

These values were decided upon by an iterative process where feedback, from people outside of the simulation development team, on what was perceived as "natural" and on not making the differences between the different speeds too large were taken into consideration.

2.4 Procedure

In order for the study to be as optimal as possible with the assets we were given, we introduced 3 participants to a pilot study before the main study, in order to receive feedback and help develop the experiment further. Some of the feedback included a different questionnaire for the first video, as some of the questions relied on the different videos, and to showcase longer versions of the videos.

As one of the first steps of each experiment, the participants were introduced to the Heart Rate-monitor. They were told about what it measures and then they were asked to put the monitor on themselves with instructions and assistance from a team member. The study did not start until the pulse had lowered and stabilized.

The participants were presented to the structures of the experiment and that they were going to be presented with 3 videos, all similar to each other and about 25 seconds long. The videos featured a group of mannequins in the foreground with more mannequins walking in the background outside in an open space facing a brick building. The only difference in the videos was the pace of the background mannequins and placement of the foreground mannequins. Half of the subjects (5) watched the videos in order from slowest to fastest while the other half watched the videos in order from fastest to slowest. They were also asked to answer questions after each video. These questionnaires were printed and provided, together with a pen, to the participants before the experiments was initiated. We used the Likert-scale (1 to 7) for our graduated questions as a scale from 1 to 5 would appear inaccurate and a scale of 1 to 10 would have been redundant.

During the process the participants were given the task to start the video whenever they were ready, after they had seen the video they could write their answers on the questionnaire. During the entire experiment session the participants' pulse and potential changes of pulse was recorded by the Heart Rate-monitor.

3. Result

3.1 Perception of Mood

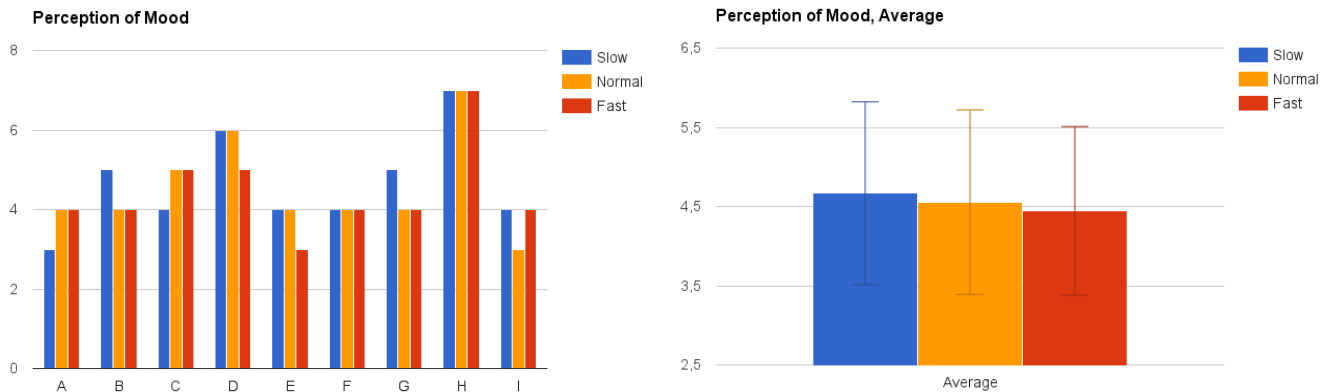


Fig 1. Perception of Mood. The different colors correspond to each simulation with its respective pace. In the first graph, the Y-axis corresponds to the rating where 1 = negative, 4 = neutral, 7 = positive. The X-axis corresponds to each participant.

The participants were asked to rate their perception of the mood and feeling of stress for each simulation, from which the results can be seen in figure 1 and 2. As for the first diagram, which depicts the general mood of the scene, the answers were varying but had a similar average. Here most participants kept their rating around a neutral score or towards the positive side of the scale. Judging from the average, the slow paced simulation was perceived to be slightly more positive, followed by the normal pace and finally the fast pace.

Some participants judged the mood on the non-walking characters in the foreground, where subject *I* described the hand movements as somewhat aggressive. Subject *D* specifically mentioned that they rated the mood as more positive for the slow paced simulation because of the slower walking pace of the background characters.

3.2 Perception of Stress

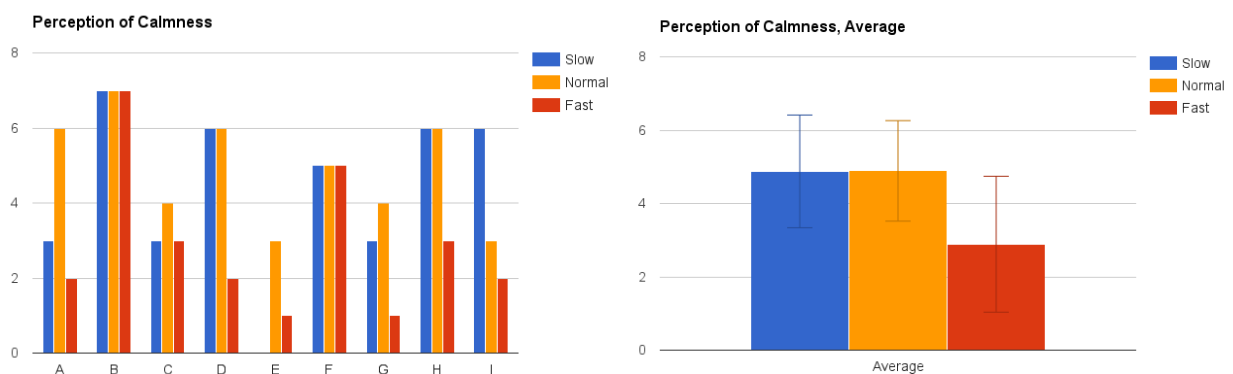


Fig 2. Perception of Calmness
The participants were asked to rate their perception of calmness in the visual stimuli, where 1 = stressed, 4 = neutral, 7 = calm

The second figure shows the responses for perceived stress or calmness, where the results were even more scattered than in figure 1. The participants mostly judged the fast paced simulation to be the most stressful, while the other two received different scores. 3 out of 9 perceived the slow paced simulation to be more stressful than the normal paced one. In 5 out of 9 cases, the slow and normal paced simulations were rated equally. The subjects that commented on their perception of higher stress levels mentioned the moving crowd as the primary contributing factor.

3.3 Heart Rate

Subject	Slow	Normal	Fast		
A	71,6	76	72,6		
B	92,2	96	99,7		High
C	106,2	100,3	99,3		Middle
D	88,2	87,9	88,8		Low
E	80,9	79,8	78,8		
F	93,7	91,5	91,9		
G	91,5	92,2	84		
H	72,5	73,3	71,2		
I	91,9	89,7	90,9		
Average:	87,63333333	87,41111111	86,35555556		
Std Deviation:	10,36704179	8,642844753	9,913751517		

Fig 3 - Average heart rate in beats/minute. Colors indicate the slowest (green), middle (yellow) and highest (red) rate for each participant.

Figure 3 describes the heart rate in beats/minute for each participant and simulation. According to the average value, the slowest pace resulted in the highest pulse, while the fastest pace had the lowest. This goes against the written responses, where the result was the other way around. Looking at figure 4 and 5 below, the average heart rate was reversed depending on the order of the simulation. Here the subjects who watched the simulations from slow to fast had a higher heart rate from the slow simulation, while the participants who watched in reverse order had a higher heart rate from the fast simulation.

Subject	Slow	Normal	Fast
A	71,6	76	72,6
C	106,2	100,3	99,3
E	80,9	79,8	78,8
G	91,5	92,2	84
I	91,9	89,7	90,9
Average:	88,42	87,6	85,12

Fig 4 - Heart rate in beats/minute for participants who watched the simulations from *slow to fast*.

Subject	Slow	Normal	Fast
B	92,2	96	99,7
D	88,2	87,9	88,8
F	93,7	91,5	91,9
H	72,5	73,3	71,2
Average:	86,65	87,175	87,9

Fig 5 - Heart rate in beats/minute for participants who watched the simulations from *fast to slow*.

3.4 Attention

Each participant was asked where in the scene they tended to focus at first, and 6 out of 9 mentioned that they mainly focused on the non-walking mannequins in the foreground. The moving crowd in the background was rarely commented on, but received more attention after the first simulation. This was a conscious choice by us as we did not want the subjects to know what to look for in the simulation and thus skew the results.

4. Discussion

4.1 Discussion of Results

With this study we have examined the perception of crowds moving, where a faster pace seems to result in a higher perceived stress in a static individual. A reason for this could lie in a biological mechanism called attentional capture, meaning that movement catches attention, along with a theory by Turatto et al (2006) that attention on a moving object actually increases its perceived speed.

An interesting result was that two out of the nine subjects answered that the foreground mannequins in the second video felt more aggressive and jerky, as opposed to the first video. The only change in the different videos was the pace of the background mannequins, while those in the foreground remained untouched. One theory is that the subjects, still focusing on the foreground, subconsciously noticed a difference in speed and projected it onto the mannequins, perceiving them as more aggressive. It might also not indicate anything, as two other subjects found the second video to be even calmer than the first one according to the questionnaire. Another theory is that, while the difference in pace between the first and second was larger than the difference in pace between the second and third, the subjects did not notice the change in pace. Instead, they tried to look for any difference, and although not the case, found that they seemed more aggressive.

When designing the study, we learned that it was difficult to give a concrete definition of what stress actually is, and how it manifests. Because of this, we decided not to ask the subjects questions about our idea of what stress means, and instead ask open questions like “On a scale of 1 to 7, how stressful did you perceive the setting to be?”. This could be a reason why the correlation between pace and perceived stress is so strong, while the correlation between pace and heart rate is practically non-existent in this case.

Judging by the responses from the participants, where some compared the crowds behavior to actual behavior in real life, it would seem like the results could be close to a real setting outside of a virtual simulation. It must however be noted that when studying simulated perception in a virtual environment, one must also study the effect of the technology on the individual (Veen, 1998). As such, it would be of great interest to compare the results of this study to the results of a setting with a real crowd, in order to truly see how and if the virtual environment can be used instead of the latter.

4.2 Method Criticism

While the subjects did not show any significant difference in heart rate in the videos, there was a clear correlation between the perception stress and the pace of the video. This could have several reasons, e.g. better use of the heart rate monitor, using a greater sample size or planning the study differently, all of these parameters discussed below.

When conducting this study it was not possible to provide the participants a separate room that could guarantee that no interruptions or distractions would occur. Instead, during some of the experiment sessions there was movement in the background in the form of people entering and exiting the room, which could have affected the attention and focus for the participants.

Though the environment provided to the participants was not optimal, the use of headphones may have prevented some distractions during the experiment. Furthermore, the subjects were observed during the entire session, and if they gave any indication to be distracted it would be noted and the results would have been discarded.

Originally, our study meant to include the 4K big screen used in the VIC study, but due to time constraints we had to disregard that asset and instead use a 15 inch laptop screen. Using the 4K screen would have given the subjects a more immersive experience, however it is unclear whether this had any impact on the result of the study.

We had a clear purpose as to why we showcased half of the videos in one order, and the other half in the opposite order. This was mainly to prevent a lowered heart rate after the subjects had sat down for some time. After receiving feedback on the poster, we realized that a better way to solve this issue would be to randomize the order of the videos. This would also solve other problems, such as pattern recognition.

One method would be to follow the Latin square pattern. This means that instead of presenting each of the videos once in the order from slow to fast or fast to slow, they are presented several times in a predefined random pattern. This would lead to the participants not creating an expectation of the videos that they had not seen yet beforehand. This would be a method to eliminate the potential risk of participants responding that they experienced a video to be more calm based on what they are able to see a pattern and therefore beforehand tell when a slower paced stimuli is going to be presented to them.

Furthermore the directions of the walking mannequins in the visual stimuli could have an impact on how the participants perceive the movement of the crowd. In our study, the mannequins moved in different directions when examining them within their 3-dimensional environment. However, in the video format they were presented in a 2-dimensional environment. Not all of the mannequins moved directly along the X-axis in the latter, some had movements directed more towards, or away from, the viewer. Meaning that for the different paced videos there were examples of mannequins that from a 2-dimensional perspective did not change their positioning on the screen as much while the change in pace was more visible for others. If all of the mannequins had walked in a more unison direction this would be a method to eliminate the risk of having some of them being perceived as walking in a slower pace than others though they are meant to be perceived to walk in the same pace.

4.3 Future Developments

It has been recorded that people are walking 10% faster now than in 1990. One possible further development of the study based on this data could be:

How does the environment that people live in affect the result? Do culture have an impact on the perception of stress?

Another possible development to this study could be to use other immersive media to present the visual stimuli. An example would be to use Virtual Reality (VR), and present the environment to the participants. With this method it would be possible to for example introduce the participants with the opportunity to not only observe the crowd, but become a part of it. This could result in another perception of the movement of the crowd.

However this method was not considered for this study as it provides visual stimuli in an environment where the participants decide where to keep their attention more freely and no solution to this potential disadvantage was developed.

4.4 Assessment of Group Work

The work was initially divided into two main tasks; creating the scene in Unity and writing the report. However, since the report and study ended up taking more time to implement than the actual Unity-project, the team originally assigned to coding also worked on the report. In conclusion, all team members shared a close to equal workload and made sure to contribute where and when it was needed.

5. Conclusion

As previously mentioned, the small number of test subjects in this study makes it difficult to draw any general conclusions regarding perception of a moving crowd. But even though the responses were varied, some trends could be noticed. The majority found the fastest paced simulation to be the most stressful, while the normal and slow simulations received a more equal rating. Additionally, a slower pace resulted in a more positive atmosphere according to the participants. The heart rate in this case showed no correlation to the responses, but could probably give more accurate results if used on more subjects during a longer time period. Another observation was the fact that some participants tended to focus on the mannequins in the foreground, and perceive them to move faster when it was really the background crowd that increased its pace. This could be an indication that a crowd does affect the individual even if it is on a subconscious level. If that is the case, it would make sense that a crowded area and the behavior of the walkers contributes to the increased stress in today's society. Additionally, studying the everyday perception of humans through an animated simulation cannot replace a real life setting, but it gives an idea of the underlying mechanisms of how we perceive our surroundings.

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7. Appendix

7.1 Questionnaire

Denna studie handlar om hur man påverkas av en virtuell folksamling. Du kommer att få se 3 filmklipp (å 25 sekunder) med paus i mellan för att svara på frågor om respektive film. Tänk på den allmänna stämningen och hur du känner när du ser filmen.

Film 1

1. Var i filmen skulle du säga att du fokuserade mest?

2. På en skala mellan 1-7, hur skulle du beskriva stämningen i filmen? Ringa in där du tycker att följande passar in:

1	2	3	4	5	6	7
Negativ			Neutral			Positiv

Kommentar:

1	2	3	4	5	6	7
Stressad			Neutral			Lugn

Kommentar:

3. Vad kände du själv när du såg filmen?

Film 2

1. På en skala mellan 1-7, hur skulle du beskriva stämningen i filmen? Ringa in där du tycker att följande passar in:

1	2	3	4	5	6	7
Negativ			Neutral			Positiv

Kommentar:

1	2	3	4	5	6	7
Stressad			Neutral			Lugn

Kommentar:

2. Vad kände du själv när du såg filmen?

Film 3

1. På en skala mellan 1-7, hur skulle du beskriva stämningen i filmen? Ringa in där du tycker att följande passar in:

1	2	3	4	5	6	7
Negativ			Neutral			Positiv

Kommentar:

1	2	3	4	5	6	7
Stressad			Neutral			Lugn

Kommentar:

2. Vad kände du själv när du såg filmen?

7.2 Responses

1 - Negativ/Stressad

7 - Positiv/Lugn

A (Film 1->3)

Film 1:

1. På de som stod i förgrunden och viftade
2. 3 av 7 - Hetsiga rörelsemönster
- 3/7 -
3. Inget speciellt....

Film2:

1. 4/7 -
- 6/7 -
2. Lugn

Film 3:

1. 4/7 -
- 2/7 - Alla i bakgrunden gick så snabbt
2. Stressad

B (Film 3->1)

Film 1:

1. På personernas armrörelser i början. När det uppträdde likadant kollade jag på omgivningen.
2. 4/7 - En vanlig skoldag
- 7/7 - Inget oroade mig
3. Ingenting speciellt

Film 2:

1. 4/7 - Samma som förra, varken glad eller negativ
- 7/7- Personerna var om möjligt ännu lugnare
2. Inget speciellt

Film 3:

1. 5/7 - Personerna i bakgrunden gick långsammare kändes det som. Dvs personerna har mindre bråttom -> positivare
- 7/7 - Allt var superlugnt
2. Inget speciellt. Försökte analysera kritiskt vad jag såg.

C (Film 1->3)

Film 1:

1. Överallt, svårt att fokusera på ett ställe. Mest bakgrunden
2. 4/7 -
- 3/7 -
3. Förvirrad

Film 2:

1. 5/7 -
- 4/7 - Mindre "oväsen"
2. Ingenting, neutral

Film 3:

1. 5/7 -
- 3/7 - Mer speed, alla gick fortare
2. Kändes som en vardag - normalt

D (Film 3->1)

Film 1:

1. Jag fokuserade mest på de som stod längst fram, närmast "kameran"
2. 5/7 -
2/7 - Det var mycket folk i rörelse i bakgrunden, men de som stod närmast verkade inte stressade
3. Jag kände en neutral känsla, men lite stressad när jag tittade på de i bakgrunden

Film 2:

1. 6/7 - I jämförelse med den första filmen kändes stämningen mer positiv i.o.m att det var en mycket lugnare stämning också.
6/7 - Människorna i bakgrunden upplevdes lugnare
2. Jag fokuserade nog mer på stämningen i helhet och den upplevdes lugnare och trevligare.

Film 3:

1. 6/7 -
6/7 - -
2. Den kändes ungefär som den föregående filmen. Jag fick samma känsla av att den var lugnare och därmed även mer positiv än den första.

E (Film 1->3)

Film 1:

1. Den grupp av människor som stod i mitten
2. 4/7 -
NULL
3. En vanlig dag på KTH kändes det som

Film 2:

1. 4/7 -
3/7 - -
2. Det var ganska hackiga rörelse på figurerna vilket tog min uppmärksamhet

Film 3:

1. 3/7 -
1/7 - -
2. Det var ett väldigt högt tempo vilket gjorde att jag kände mig lite obekväm

F (Film 3->1)

Film 1:

1. Till höger vid rampen
2. 4/7 -
5/7 - -
3. Lugn, i en alldaglig miljö

Film 2:

1. 4/7 -
5/7 - -
2. Liknande känsla som föregående film

Film 3:

1. 4/7 -
5/7 - -
2. Lugn

G (Film 1->3)

Film 1:

1. Gubben med ticks till höger
2. 5/7 - Något glatt/ljust ljud i bakgrunden. Mlt folk men inte "påträngande"
3/7 - Lantis, van vid lite folk
3. Vet inte

Film 2:

1. 4/7 -
4/7 - Upplevdes som mindre folk i rörelse allmänt
2. NULL

Film 3:

1. 4/7 - Fortfarande neutral konversationsnivå
1/7 - Mer folk, snabbare tempo. Gestikulerade mer
2. Typiskt stockholm i bakgrunden
- 3.

I (Film 1->3)

Film 1:

1. Gruppen av människor till höger och vänster, samt bakgrunden
2. 4/7 -
6/7 - Ljudnivån var ganska låg och alla gick relativt långsamt
3. att det såg ut som KTH, inget speciellt

Film 2:

1. 3/7 - Personerna i förgrunden slängde mycket med armarna vilket jag kände var lite aggressivt
3/7 - Personerna i bakgrunden gick lite snabbare
2. inget speciellt

Film 3:

1. 4/7 -
2/7- alla verkade röra sig väldigt snabbt
2. att det gick lite för fort