12-2017

Relative Importance of Different Body Channels to the Believability of a Stylized 3D Character Animation in a Full Body Shot

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RELATIVE IMPORTANCE OF DIFFERENT BODY CHANNELS TO THE BELIEVABILITY OF A STYLIZED 3D CHARACTER ANIMATION IN A FULL BODY SHOT

by

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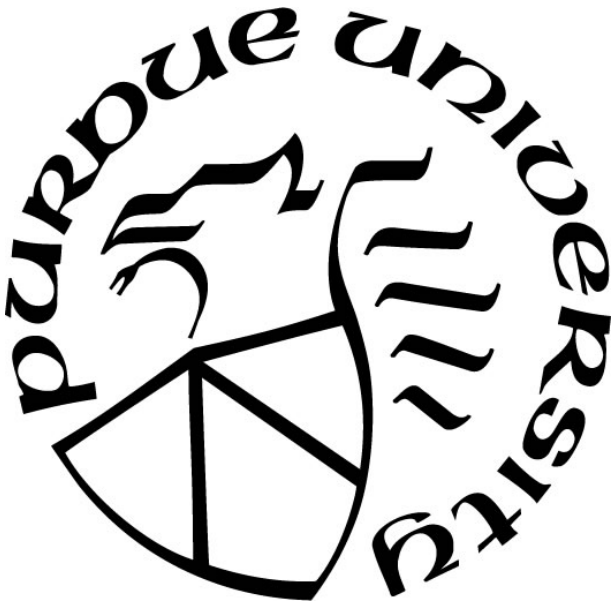
A Thesis

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Master of Science



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West Lafayette, Indiana

December 2017

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This thesis is dedicated to my family, for their wholehearted support and encouragement and also to Dhiraj Bodicherla & Krishna Singhal for making the journey fun.

ACKNOWLEDGMENTS

I sincerely thank my advisor Prof. Nicoletta Adamo-Villani for being a great source of support and guidance throughout my Master's degree. My heartfelt thanks to my other committee members, Dr. Hazar N Dib and Prof. Raymond P Hassan. I also want to thank Angie Schutz, Cathy Noerenberg & Regina M Brown for being patient and very helpful.

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ABSTRACT

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Degree Received: December 2017
Title: Relative Importance of Different Body Channels to the Believability of a Stylized 3D Character Animation in a Full Body Shot.
Major Professor: Nicoletta Adamo-Villani

Character animation involves movement in different channels of the character's body. There is a norm in the animation industry that each of these different body channels has varying contributions to the believability of an acting performance: body movement being the highest contributor and lip sync the lowest. This thesis investigated this norm using statistical analysis. While the reduction of body motion caused the biggest drop in believability, similar reductions in facial animation and lip sync have not made a significant effect on the believability. The only exception to the above statement is the animation depicting the emotion sadness, where no significant effect was found for any of the body channels. Also, the emotion anger seems to have an interaction between the participant background and the body channel. Here, the participants from Computer Graphics background gave lower believability ratings compared to the ones without it. To generalize, when it comes to a stylized character animation in a full body shot, it does appear that biggest contributor to the believability is the body motion while it appears that the reduction in facial and lip sync animation does not impact the believability as much as the reduction in body motion.

CHAPTER 1. INTRODUCTION

Much like acting, character animation involves movement in different channels of the character's body. In an action like walking, the action starts with the hips. As the hip swings forward, it sets a leg in motion. As the hip twists, the torso follows, then the shoulder, the arm, the wrist, and finally the fingers. The eyes will usually lead the head in an action (Lasseter, 1987, p. 39).

It is well known in the animation industry that each of these different body channels have varying contributions to the believability of an acting performance. Shawn Kelly is a Senior Animator at Industrial Light & Magic. Kelly (2008) says, "most animators would agree that the body language and pantomime is by far the most important aspect of the overall acting performance in a medium shot or wider."

In a full body shot, the norm is that the movement of limbs, torso and head is the most important, followed by eyes/eyebrows, face and lip sync in the decreasing order of importance. John Lasseter says that when the main idea of an action is being told in the movement of the body, the facial expression become subordinate to the main idea (Lasseter, 1987). Shawn Kelly (2008) says, "one can break down an acting performance into four categories of exponentially decreasing importance: the body, then the eyes, then the face, then the lip-sync." According to researchers, up to 93% of human communication is made up of body language (Larsson, 2014). Aviezer, Trope and Todorov (2012) say that body cues, not facial expressions, discriminate between intense positive and negative emotions. Ward (2014) feels that it is important to concentrate on the body language initially, as it plays a huge role in the way we read what a character is trying to say and can convey how they are feeling. Roberts (2011) says, "when animating your character, because facial expressions can be very ambiguous and misleading, it is always best to work out the body language first and then add the facial expressions" (p.329).

According to Keith Lango (2004), "After the body, the eyes are key in emotional communication. If you have great body animation and great eye-emotion animation, you don't need a mouth to get the point across." Garrison and Wang (n.d.) say, "If the camera is capturing a long shot of you off in the distance, concentrating on arching your eyebrow

to convey emotion will just be a waste of time since the camera won't be able to see it." Body language in animation represents the most important element of an acting performance in a medium to wide shot (Kelly, Baena, Sintay, Gilman, & Gilbert, 2009).

As understood from the above sources, it is widely agreed upon that body language is more important than facial expressions in a 3D animated full body shot. However, it has not been scientifically proven. The researcher intends to test this norm scientifically.

This chapter establishes a basis for the completion of this research study. This is achieved through the description of the scope and significance of the research. This description leads to the research question.

1.1 The Scope

The relative importance of animating different body channels to the final acting performance will be tested in this research. This research involves the animation of a stylized 3D character in a full body shot with three-quarter view. Four different versions of the same animation will be created. Three versions will have animation toned down for one of the following: limbs/torso/head, eyes/eyebrows/face and lip sync. The toning down is achieved by reducing the magnitude of all the keyframes on a body channel by half. This is achieved by using Autodesk Maya's animation layers. The fourth version will have all the channels animated without any toning down. These four animations are shown to users and they will be asked to rate them in terms of believability. Each version of animation will be of roughly 10 seconds in duration. The set of four animations will be made for each of the five emotions: happiness, sadness, anger, fear and surprise. So, a total of 20 animations will be created and used for user ratings.

1.2 Significance

In character animation of a full body shot, the norm is that the movements of limbs, torso and head are the most important, followed by eyes/eyebrows, face and lip sync in the order of decreasing importance (Kelly, 2008). But, this norm is not tested scientifically. This research intends to test this norm scientifically, thereby adding to the

field. This research can also help animators in prioritizing their time in animating different channels of a character, by spending their time proportional to the contribution made by the specific body channel to the believability of the animation.

1.3 Research Question

In a stylized 3D character animation of a full body shot, what is the contribution of different body channels to the representation of motion?

1.4 Assumptions

The research is performed with the following assumptions:

- The model/rig that is going to be used in this research does not evoke any kind of emotions in its neutral state. This will make sure that no emotion has an effect on the animations of any of the other four emotions.
- All the participants will be honest with their survey answers. To justify this assumption, the participants will be explained how their anonymity and confidentiality are preserved. Also, they will be notified that they may choose to withdraw from the survey without any ramifications.
- Since the animations involve audio in English language, it is assumed that all the participants of the survey can understand English.

1.5 Limitations

The research is limited by the following:

- Since the research deals with character animations, the results may be affected by the animation feature films that will be playing in theatres during the time period of the testing.
- The participants are assumed to be reasonably good at distinguishing the believability of animation among the four animations. This is important because of the fact that the survey asks the participants to rate the animations based on their believability.

1.6 Delimitations

The research is performed acknowledging the below delimitations:

- The research does not involve animations using a realistic model/rig or even realistic body motion. This is to avoid the impact of uncanny valley on the research (Uncanny valley, n.d.). Also, this makes the research more practical to finish in the timespan by narrowing the scope.
- The research performs animation tests only for five of the seven famous emotions: happiness, sadness, surprise, fear, anger, disgust and contempt. This again is to make the research more practical to finish.

1.7 Definitions

Lip Sync: To move the lips in synchronization with recorded speech or song.

Three-quarter view: Depicting the subject turned slightly from a full frontal view.

Key frame: A frame in an animated sequence of frames which was drawn or otherwise constructed directly by the user rather than generated automatically, e.g. by tweening.

1.8 Summary

This chapter provided the scope, significance, research question, assumptions, limitations, delimitations, definitions, and other background information for the research project. The next chapter provides a review of the relevant literature.

CHAPTER 2. REVIEW OF RELEVANT LITERATURE

Films have been using Computer Generated Imagery (CGI) in their films for over two decades. 3D animations are becoming more and more popular. Dozens of films each year are made in CGI (Shaver, 2011). Character animation is a specialized area of the animation process, which involves bringing animated characters to life. The role of a Character Animator is analogous to that of a film or stage actor, and character animators are often said to be "actors with a pencil" (or a mouse) (Character animation, n.d.). According to Riki (2013), it is common for feature animation (in 3D) to go at the pace of about 3-4 seconds of animation per week. Riki (2013) says that speed at which one animates really only matters when a deadline is fast approaching. If an animator is working at a large studio that needs things done as soon as possible, she may have to work at a much higher rate (and lower quality) than if it is a personal shot. In a situation like this, where there is a looming deadline, the animators need to prioritize their animation. It may not be worth animating every body channel (body, face, eyes, lips etc.) with high quality. Shawn Kelly (2008) says, “one can break down an acting performance into four categories of exponentially decreasing importance: the body, then the eyes, then the face, then the lip-sync.” Even though the above statement made by Shawn is a well-accepted norm in the animation industry, it has not been scientifically proven. This research intends to find out if there is indeed an order of decreasing importance for different body channels with respect to their contribution to animation. Based on this research, animators can pay extra attention to a few body channels than others, thereby saving valuable time in crunch situations.

There is a significant amount of literature on the importance of different body channels in an acting performance in both live-action and theatre. Research has also been done on the importance of these body channels with respect to 3D character animation. However, none of these researches looked at the relative importance of the different body channels in making a believable character animation. This review discusses the existing literature and provides the necessary foundation for testing the research question.

2.1 Literature Review Approach

This review of literature is organized in the following order:

1. Components of body language.
2. Contribution of different body channels to acting/theatre.
3. Contribution of different body channels to a 3D character animation.
4. Importance of acting in animation.
5. Similarities between animation and acting/theatre.
6. Justification for the choice of emotions.
7. Justification for the choice of shot.
8. Justification for the choice of animation (Stylized vs Realistic).
9. Justification for the Choice of Model/Rig
10. Summary of the literature review

2.2 Components of Body Language

According to Bartneck (2001), the main components of body language are facial expressions, gestures and body movement (p. 282). There is no difference in the relative importance of the components of body language (Ekman et al., 1980).

Non-verbal cues make up the majority of a conversation (Larsson, 2014, pp. 6-7). Janine Driver (2008), a body language expert, claims it to be a whole 93%. These non-verbal cues include the tone and pitch of voice, posture, micro expressions on the face as well as different gestures. According to Larsson (2014), body language is sectioned into three bodily attributes, the face, the body and the tone of voice. Although it has been widely assumed, probably over centuries, there is no real evidence that the face is a stronger communicator than the body (Larsson, 2014, pp. 6-7).

Aviezer, Trope and Todorov (2012) believe that during peak intensities of emotion, positive and negative situations were successfully discriminated from isolated bodies but not faces (p. 1225).

A significant amount of research shows that some affective expressions may be better communicated by the body than the face (Argyle, 1988, Bull, 1987, De Gelder, 2006). Body expressions may provide more information than the face when

discriminating between fear and anger (Meeren, van Heijnsbergen, & de Gelder, 2005) or fear and happiness (Van den Stock, Righart, & De Gelder, 2007). Most of the studies mentioned in this sub-section highlight the importance of bodily expression for an emotion.

2.3 Contribution of Different Body Channels to Acting/Theatre

This sub-section explores the literature that highlights the importance of different body channels to an acting performance.

For an acting performance, bodily movements can sometimes signal an intention that cannot be derived from facial expressions (e.g., approach and avoidance behavior) (Keefe, Villing, Racey, Strong, Wincenciak, & Barraclough, 2014, p. 1042).

When it comes to the importance of eyes in an acting performance, what actors do with their eyes characterizes their roles. Cohen (2011) says:

> When truly engaging with the other characters in the play—that is, when anticipating, judging, admiring, scaring, attracting, dismissing, and penetrating them—an actor's eyes, and the way she employs them, will tell us as much or more about her character as does her costume, makeup, diction, accent, movements, and, in many cases, even her words. It is an important truth about acting, and a rarely realized one, that you act not just with your voice and your body and your emotions and ideas, but with your eyes. Eyes that seek answers to your character's questions, and victories for your character's goals; eyes that penetrate the other actors on the stage; eyes that create the living energy of the dramatic action; eyes that enhance the conviction and authority of the performances, the sharpness and edginess of the characters, the engagement and empathy of the audience, and the increasing momentum of the play itself. The eyes become both the defensive and offensive weapons of the actor's character. They mirror the soul, yes, but they also reveal the characters' minds and propel the dramatists' actions (Cohen, 2011).

According to Daniel McNeill and Dan McNeill (2000):

> The eyebrow is the great supporting player of the face, and its work generally escapes notice. It helps signal anger, surprise, amusement, fear, helplessness,

> attention, and many other messages we grasp almost at once. Indeed, without eyebrows the surprise expression almost disappears. The eyebrows are such active little flagmen of mind-state it's amazing anyone can wonder about their purpose. We use them incessantly (p. 199).

The studies discussed in this sub-section show the importance of different body channels and their contribution to an acting performance.

2.4 Contribution of Different Body Channels to a 3D Character Animation

This sub-section examines some important studies that highlight the contribution of different body channels to a 3D character animation.

Maestri (2006) explains about the importance of facial expression to depict an emotion. He says, "facial expressions convey a lot of emotion, and it's very important to understand these expressions and the way the face communicates emotion."

The amount of information expressed through the body alone should not be sufficient for an observer to recognize the emotion, since most of the information is expressed through the facial expressions, the speech prosody and, importantly, verbal content (Volkova, Mohler, Dodds, Tesch, & Bülthoff, 2014, p. 2). However, according to Volkova et al., the results demonstrate that the information contained in upper body motion in natural scenarios is enough for people to recognize emotion (Volkova, Mohler, Dodds, Tesch, & Bülthoff, 2014, p. 10).

According to Hohnstadt (2013), bodily expression is the most important contributor to the believability of 3D character animation. He says, "The face can provide a wealth of story-telling data with just a simple expression. Rarely, though, does the whole story come just from the head. By using the entire body, and really pushing your poses, you can achieve a better sense of story and scene than you ever will with faces alone."

Hooks (2013) says that a character's body language is going to transmit a more powerful message visually than his dialogue (p. 47).

Bird (2010) explains how bodily expression becomes much more important when the character is framed in a full body shot. He says, "Body language is a great contributor to helping the face convey the appropriate expression and emotion needed. This is

especially important when the face can't be relied on, like in shots where the character is seen from far away or when the character's face is obscured or hidden."

Bartošová (2011) explains how the whole body of a character can contribute to a believable character animation. She says, "Whole body movement supports the message an animator wants to communicate. Gestures help to express emotions clearly and emphasize a point. The movements of the eyes, mouth, and facial muscles create a connection with the audience. People want to identify with the characters, feel their emotions and live their story with them through the screen" (pp. 17-18).

Navone (2009) explains the importance of eyebrows by saying, "Eyebrows are hugely expressive, and are capable of bigger shape changes than the eyes alone, and often read better from a distance. Brows also change the shape of the eye; make the shape of your character's upper lids echo the shape of the brows so they feel connected and fleshy."

Atkinson (n.d.) feels that lip sync is not as important to a character animation in comparison to the gestures that the character makes. He says:

> Talking heads can be boring and, without the richness of detail and texture found in real-life faces, animated ones are even more so. Gestures can tell us something about the personality of a particular character and the way it is feeling. Give your character something to do during the dialogue sequence. The use of hand, arm, body gestures and facial expressions, in fact involving the whole body in the delivery of dialogue, makes for something far richer to look at than just watching the mouth itself move. These gestures may wild and extravagant, a jump for joy, large sweeps of the arms, or as small and subtle as the raising of an eyebrow. Pointing, banging the table, a shrug of the shoulders, anything may be useful to emphasize a word in the dialogue or to pick up a sound accent which helps gives the audience a clue as to what the character is feeling and absolutely gives the animated character ownership of the word.

According to Kelly (2008), an animator can work on lip sync as the last task with lesser priority when compared to other body channels. He says:

> Great body acting paired up with expressive and alive eyes, combined with well-timed facial expressions -- that combination is going to look terrific, even without the lip-sync. This is why you'll hear a lot of people say that lip-sync is the icing

> on the cake of the overall animation. It's that last extra little bit of "wow" you can add to your scene, and by far the least important aspect of your acting performance. None of this is to say that any of these four categories are unimportant, some are just more important than others. Really terrible lip sync will certainly ruin a shot on a demo reel, but my point is that mediocre lip sync combined with otherwise great animation will probably go unnoticed, and the recruiter will be left with a feeling that the overall shot was great, even though the lip-sync itself might not have been fantastic. So, I guess as far as which is the icing on the cake, it sounds like the eyes are the icing on the body language cake, the facial expressions are the icing on the eyes, and the lip-sync is the icing on the face.

Glebas (2013) echoes Kelly's (2008) views on the importance of lip sync from the above paragraph. He too feels that lip sync is not so important in comparison with other body channels. He says:

> Many animation books teach how to provide specific lip shapes to match the sounds and syllables of the speech. This is important for traditional classical animation but it is not the most important thing. A living personality breathing life into your character is more important than matching specific lip shapes. The eyes are just as important as the mouth for believable lip sync. If your character appears alive, most likely the audience will believe the lip sync (p. 112).

2.5 Importance of Acting in Animation

This sub-section discusses the importance of acting in animation. As a consequence, most of the principles that are applicable to acting/theatre apply to animation as well.

John Kundert-Gibbs and Kristin Kundert-Gibbs (2009) explain the importance of acting to animation as below:

> As an animator, you are basically doing the job of an actor. You are creating a living, breathing character that tells a story, shares an experience, and moves an audience. Your character becomes "animated" with the body, voice, and emotions that you breathe into it. So you need to understand the process of creating a real,

> living, breathing character on the screen from the actor's perspective as well as from the perspective of the CG artist (p. xiii).

Webster (2012) feels that other than mastering animation timing, performance is perhaps the key skill for animators who create character-based animation (p. 289).

2.6 Similarities between Animation and Acting/Theatre

This sub-section explores the similarities between character animation and acting/theatre.

According to Hooks (2013), Walt Disney borrowed storytelling and editing techniques from live action filmmaking and produced the first animated feature film, Snow White. Instead of real flesh-and-blood-actors giving the performances, animated characters would do it (p. 6). He explains how animation and acting follow the same principles by saying, “Stage actors act in the present and fleeting moment, and animators create an illusion of a present moment. Same principles, very different application” (p. 7).

Niklas (2009) explains how acting is important for an animator as it is for an actor. He says that, “An animator needs to have an understanding of acting and acting rules and be able to apply these to the character on screen” (p. 11). He says that actors and animators are similar in many respects, but also very different in some. “They both frame and provide life to a character, through thoughts and feelings. The best actors act in this manner, and the best animators animate in this technique” (Niklas, 2009, p. 20).

Roberts (2004) discusses the similarity between theatre acting and animation. He says, “Animation acting has more in common with theatrical acting than live action film acting. Theatrical acting has to be big and demonstrative for the audience to see and understand what's going on. The exaggeration required for this is similar to exaggerated cartoon movement” (p. 160).

All the studies mentioned in this sub-section explain the similarities between live action acting and animation. As a consequence, it can be assumed that contribution of different body channels will also be similar between live action acting and animation.

2.7 Justification for the Choice of Emotions

The five emotions chosen for this research are happiness, sadness, anger, fear and surprise. The choice of these five emotions is justified by the following studies.

According to Cissell (2013), the standard of emotions usually consists of happiness, sadness, surprise, fear, anger, and disgust (p. 22). Volkova et al. (2014) used four basic emotion categories in their research namely, joy, anger, fear, and sadness.(p. 1).

2.8 Justification for the Choice of Shot

A full body shot is chosen for the final character animations. This sub-section is intended to justify the choice of the shot that will frame the character for animation.

In general, most animation shots do not cut close to face. Roberts (2004) explains the difficulty with close up shots in 3D character animation. He says, “Whereas film acting requires a certain amount of restraint, the camera can cut right into somebody's face and a whole range of emotions can be put over with the movement of an eyebrow. This is something that animation finds very difficult to do. The closer you cut into the face of your character, the more obvious it is that your character is artificial” (p. 160).

2.9 Justification for the Choice of Animation (Stylized vs Realistic)

This sub-section is intended to justify the choice of animation that this research uses, which is a stylized animation.

The results from a study conducted by Cissell (2013) indicated that, “for recognition, participants were more likely to recognize a stylized character although it was not a significant difference. Stylized characters were on average rated higher for sincerity and intensity and realistic characters were on average rated higher for typicality” (p. ix).

2.10 Justification for the Choice of Model/Rig

This sub-section is intended to justify the choice of model/rig that this research uses, which is a stylized rig named Malcolm rig, developed by AnimSchool.

The rig is capable of strong silhouettes which is highly important for animation as explained by Mark McDonnell (2010). He says: “The importance of a good and readable silhouette is of extreme importance no matter in it's simplest basic forms or in the complexity of a highly illustrated visual development piece!.”

Malcolm rig is widely considered to have one of the most flexible and expressive face rigs available (AnimSchool, 2015). He has a fairly large head with long limbs which makes him highly expressive in all the body channels. This makes him a good choice for this research study.

2.11 Summary of the Literature Review

This review of literature explained the different components of body language and their importance to communication and emotional expression. It explored the contributions of different body channels to live action acting as well as 3D animation.

Most of the studies concurred that bodily expression counts more than facial expression in the context of a full body shot. The review also explained the importance of acting in animation, the similarities between them which helps to apply same principles to both in terms of emotional expression.

The later part of the literature review justified the choices of emotions, the shot to frame the character, the style of animation and the model/rig that are used in this research. The next chapter explains the methodology employed for this research.

CHAPTER 3. METHODOLOGY

This chapter elaborates the method, data analysis and performance measurement used for this research.

3.1 Method

A stylized character will be used for animation using the Autodesk's Maya software. Animations will be created involving different body channels: limbs/torso/head, eyes/eyebrows/face and lip sync. These animations will be created for five emotions: happiness, sadness, anger, fear and surprise. Four different animations will be created for each emotion, with the shot, audio and lighting unchanged for a particular emotion. So, a total of 20 animations will be created for user evaluation.

Each shot will be a full body shot with three-quarter view. Within a particular emotion, one of the four animations will have all the body channels animated. The other three animations will have animation of one of the following body channels toned down: limbs/torso/head, eyes/eyebrows/face and lip sync. The toning down is achieved by reducing the magnitude of all the keyframes on a body channel by half. This is achieved by using Autodesk Maya's animation layers. Each of the four animations will be roughly 10 seconds in duration. The three toned down animations will help to find out if the body part(s) that is (are) toned down are noticeable enough to impact the believability of the animation. Once the four animations are completed, the users will be asked to rate them in the decreasing order of their believability. Due to the similarity in question structure and flow, the survey is modeled on the one from the work of S. Rajasekaran & N. Adamo-Villani (2015). The body part(s) whose toning down impacts the believability more will rank higher in their relative importance towards an acting performance. The user ratings will be used to rank the body channels in terms of their relative importance. These rankings can be calculated for the five emotions based on the user evaluation.

3.2 Population

All the students aged above 18 from the departments of Computer Graphics Technology, Computer Science, Aeronautics and Astronautics and Electrical & Computer Engineering at Purdue University.

3.3 Sampling

This research uses simple random sampling. A total of 100 responses were collected when the survey was open. However, 29 of these responses were either incomplete or faulty and were discarded. About 44% of the respondents were from the department of Computer Graphics Technology.

3.4 Variables

The research will have one control group and three experimental groups. The animation with all the body channels animated without any toning down is the ‘control group’. The ‘experimental groups’ are the animations with each of the following body channels toned down in animation in each group: limbs/torso/head, eyes/eyebrows/face and lip sync. So, there will be three experimental groups. The independent variables are the participant background and body channel. The dependent variable is animation believability. Animation believability rating is obtained from the student survey. Performance is measured using the steps discussed under the statistical analysis section below.

3.5 Design

The design is truly experimental. This research tests the null hypothesis mathematically as discussed below using statistical analysis.

3.6 Statistical Analysis

The null hypothesis is that all the four group means are equal. The alternative hypothesis is that the four group means are not equal. The statistical test ANOVA will be

used to test the null hypothesis to see if there is a statistically significant difference among the four group means. If there is a statistically significant difference, a Tukey Post Hoc test will be performed to understand the pattern of the group means. Additionally, independent samples t-tests will be performed to compare the four group means. These tests will help in providing the final rankings for the four animations for a particular emotion. The same procedure will be followed for animations under each of the five emotions, namely happiness, sadness, anger, fear and surprise.

3.7 Performance Measurement

If the ANOVA test shows that the alternative hypothesis is correct, meaning that there is a difference among the four group means, Post Hoc test and independent samples t-tests will be performed to compare each group means. Comparison will be done among group means of animations with toning down done on limbs/torso/head, eyes/eyebrows/face and lip sync and the fourth group with no toning down at all. If these groups rank in increasing order of animation believability, then it validates the hypothesis made by the researcher.

3.8 Summary

This chapter provided the method and methodology to be used in the research study. The next chapter explains the test results for each of the five emotions.

CHAPTER 4. RESULTS

4.1 Results for Each of the Five Emotions

The following sections explain the results for the five emotions. The two independent variables are participant background and body channel. The dependent variable is the animation believability. Participant background has two groups namely Computer Graphics (CG) and non-Computer Graphics (non-CG). Body channel has four groups:

- Video with all body channels animated to 100% (hereby referred to as ‘o’)
- Video with the animation of limbs, torso, head & neck toned down to 50% (hereby referred to as ‘b’)
- Video with the animation of face and eyes toned down to 50% (hereby referred to as ‘f’)
- Video with the lip sync animation toned down to 50% (hereby referred to as ‘l’)

A two-way ANOVA was performed to check the main and interaction effects. This was followed by a Post Hoc test to find the pattern in differences among group means. Finally, independent samples t-tests were performed to rank the group means. A significance level of 0.05 is used for all the calculations. The results for the ANOVA and Post Hoc tests are discussed in the following sections.

4.1.1 Happiness

A two-way ANOVA was performed to check the following null hypotheses:

- H_{01}: Participant background has no significant effect on the believability of the animation.
- H_{02}: Body channel has no significant effect on the believability of the animation.
- H_{03}: The interaction between participant background and body channel has no significant effect on the believability of the animation.

The p-values for H_{01}, H_{02} and H_{03} are 0.054, 0.000 and 0.839 respectively. So, we reject H_{02} but we accept H_{01} and H_{03}. There is a statistically significant difference in means of the four groups that correspond to the body channels.

The Tukey's Post Hoc Test was done to understand the pattern in the difference of the four group means. The pairs 'fo' and 'lo' have p-values of 0.516 and 0.955 respectively. Hence these two pairs were ignored for independent samples t-tests. The t-tests were performed for the other four pairs 'bf', 'bl', 'bo' and 'fl'.

Below are the null hypotheses for each of the above mentioned pairs:

- H_{04}: $f - b \leq 0$
- H_{05}: $l - b \leq 0$
- H_{06}: $o - b \leq 0$
- H_{07}: $f - l \leq 0$

The p-values for the above four hypotheses were 0.000, 0.000, 0.000 and 0.058 respectively. So, H_{04}, H_{05} and H_{06} were rejected while H_{07} was accepted. We can interpret from these findings that the animation 'b' with 50% animation toned down on the limbs, torso, neck and head is given a significantly lower rating than the other three groups. The differences in rating among the three groups 'o', 'f', 'l' are not statistically significant.

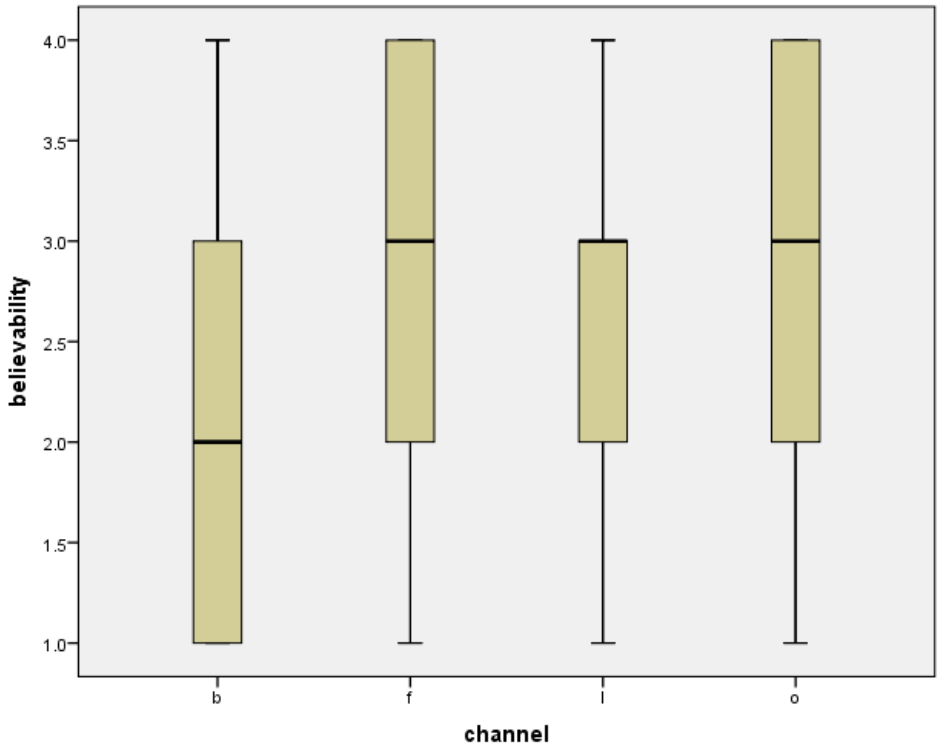

Figure 4.1. Box plot of 'body channel' for Happiness

Table 4.1 gives the mean believability ratings for the four groups while tables 4.2 and 4.3 provide the results from ANOVA and Post Hoc tests.

Table 4.1. Means of believability ratings for Happiness

Channel	Mean
b	2.06
f	3.03
l	2.72
o	2.8

Table 4.2. ANOVA results: Main and interaction effects for Happiness

Source	Sum of Squares	Mean of Squares	F-value	p-value
Background	3.562	3.562	3.739	0.054
Channel	36.971	12.324	12.935	0
background*channel	0.802	0.267	0.281	0.839

Table 4.3. Tukey's Post Hoc results for Happiness

Channel 1	Channel 2	p-value
b	f	0
	l	0
	o	0
f	b	0
	l	0.234
	o	0.516
l	b	0
	f	0.234
	o	0.955
o	b	0
	f	0.516
	l	0.955

4.1.2 Sadness

A two-way ANOVA was performed to check the following null hypotheses:

- H_{01}: Participant background has no significant effect on the believability of the animation.
- H_{02}: Body channel has no significant effect on the believability of the animation.
- H_{03}: The interaction between participant background and body channel has no significant effect on the believability of the animation.

The p-values for H_{01}, H_{02} and H_{03} are 0.084, 0.079 and 0.355 respectively. So, we accept all the three hypotheses and say that there is no statistically significant difference in means of the four groups that correspond to the body channels.

Even though the means for the four groups are in the order of ‘o’ > ‘f’ > ‘l’ > ‘b’, the differences in group means are not statistically significant.

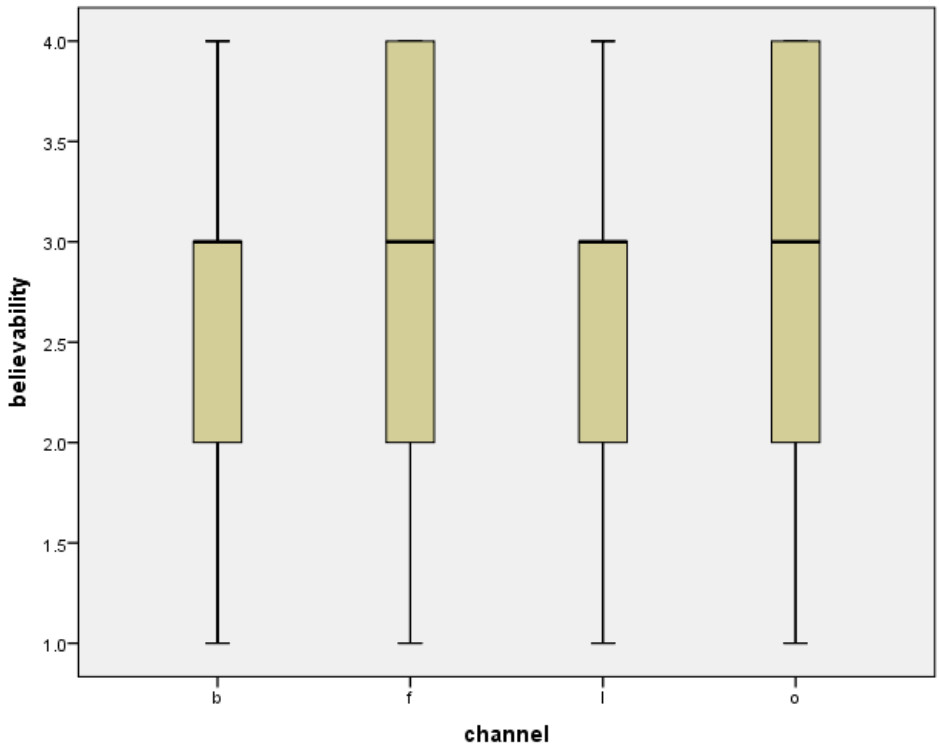

Figure 4.2. Box plot of ‘body channel’ for Sadness

Table 4.4 gives the mean believability ratings for the four groups while tables 4.5 and 4.6 provide the results from ANOVA and Post Hoc tests.

Table 4.4. Means of believability ratings for Sadness

Channel	Mean
b	2.59
f	2.8
l	2.77
o	3.01

Table 4.5. ANOVA results: Main and interaction effects for Sadness

Source	Sum of Squares	Mean of Squares	F-value	p-value
Background	2.677	2.677	3.002	0.084
Channel	6.108	2.036	2.283	0.079
background*channel	2.911	0.97	1.088	0.355

Table 4.6. Tukey's Post Hoc results for Sadness

Channel 1	Channel 2	p-value
b	f	0.543
	l	0.656
	o	0.04
f	b	0.543
	l	0.998
	o	0.543
l	b	0.656
	f	0.998
	o	0.433
o	b	0.04
	f	0.543
	L	0.433

4.1.3 Anger

A two-way ANOVA was performed to check the following null hypotheses:

- H_{01}: Participant background has no significant effect on the believability of the animation.
- H_{02}: Body channel has no significant effect on the believability of the animation.

- H_{03}: The interaction between participant background and body channel has no significant effect on the believability of the animation.

The p-values for H_{01}, H_{02} and H_{03} are 0.021, 0.000 and 0.048 respectively. So, we reject all the three hypotheses. So, it was understood that the two main effects and the interaction effect significantly affect the believability of the animation.

A one-way ANOVA was performed on the 'participant background' resulting in a p-value of 0.04 showing that there is a statistically significant difference in means of the two groups: participants with 'CG' and 'non-CG' backgrounds. An independent samples t-test was performed between these two groups with the below null hypothesis:

- H0: non-CG < CG

The test produced a p-value of 0.04. So, we reject the null hypothesis and say that the participants from the non-CG background gave significantly higher ratings to the animations than the participants from CG background. Below are the box plots for the independent variables 'body channel' and 'participant background'.

Table 4.7 gives the mean believability ratings for the four groups while tables 4.8 and 4.9 provide the results from ANOVA and Post Hoc tests.

Table 4.7. Means of believability ratings for Anger

Channel	Mean
b	2.08
f	2.89
l	3
o	3.3

Table 4.8. ANOVA results: Main and interaction effects for Anger

Source	Sum of Squares	Mean of Squares	F-value	p-value
background	4.282	4.282	5.355	0.021
channel	55.626	18.542	23.19	0
background*channel	6.387	2.129	2.662	0.048

Table 4.9. Tukey's Post Hoc results for Anger

Channel 1	Channel 2	p-value
b	f	0
	l	0
	o	0
f	b	0
	l	0.876
	o	0.035
l	b	0
	f	0.876
	o	0.202
o	b	0
	f	0.035
	l	0.202

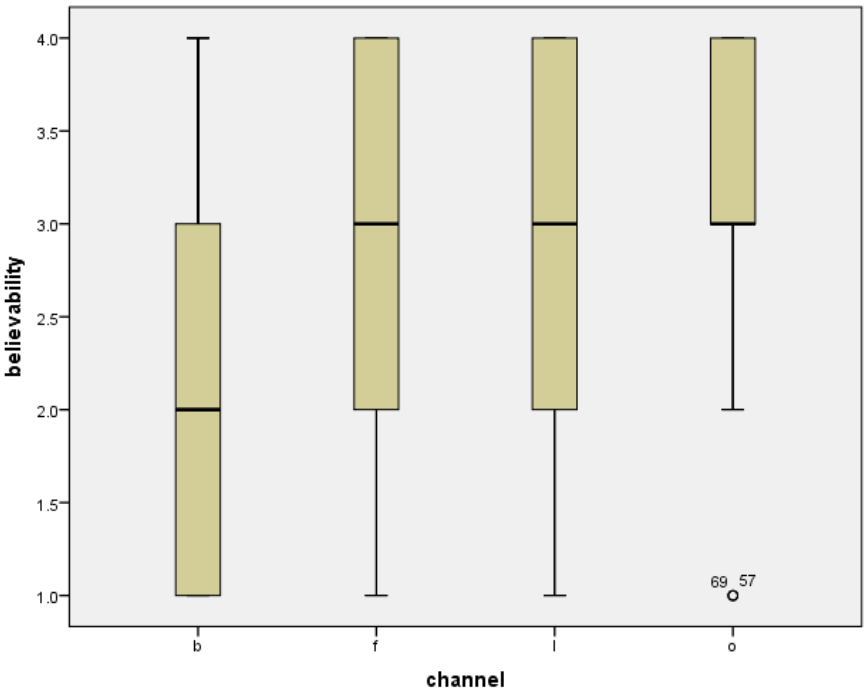

Figure 4.3. Box plot of 'body channel' for Anger

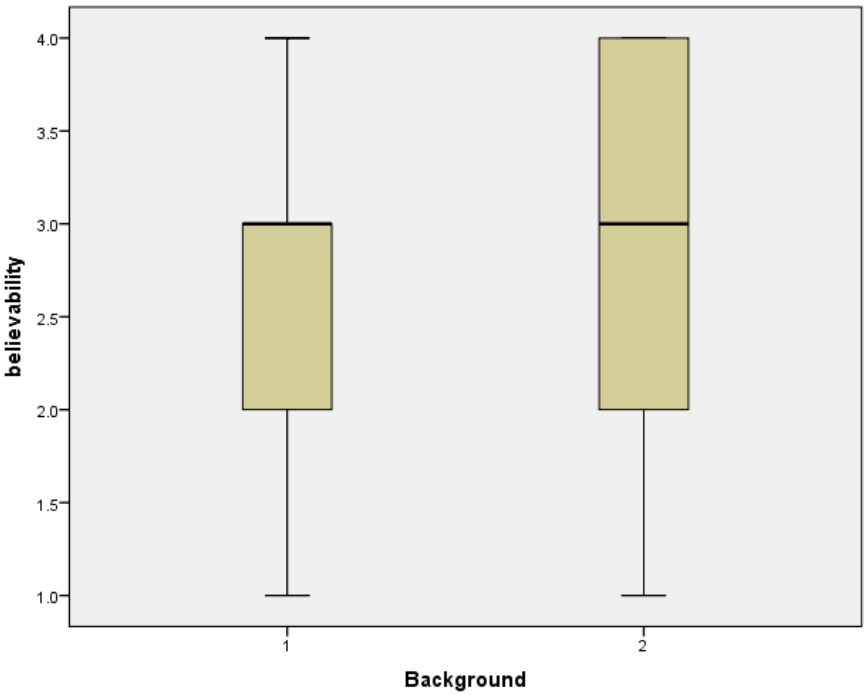

Figure 4.4. Box plot of ‘participant background’ for Anger

Below are the interaction plots for ‘participant background’ and ‘body channel’.

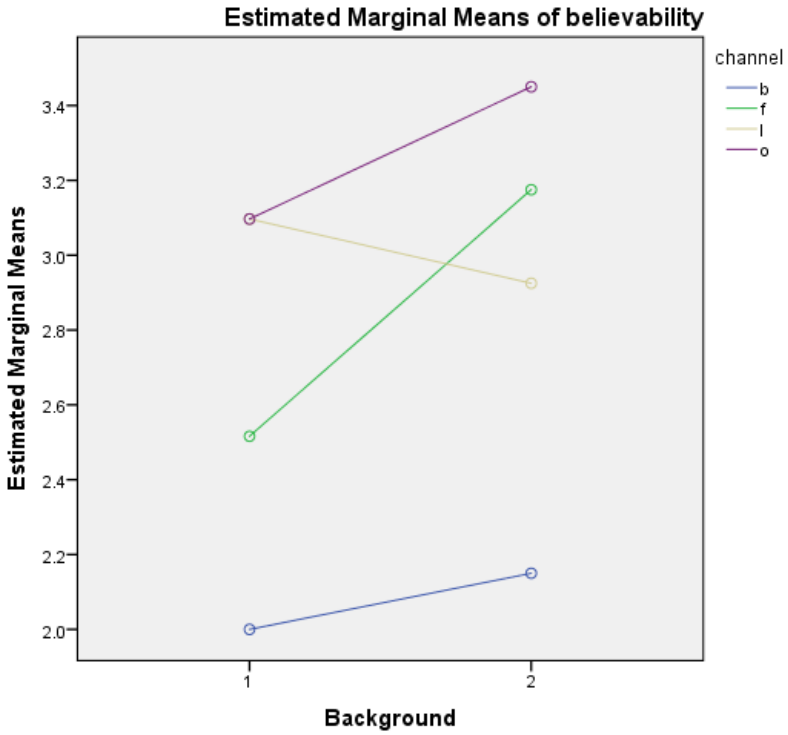

Figure 4.5. Interaction plot A for Anger

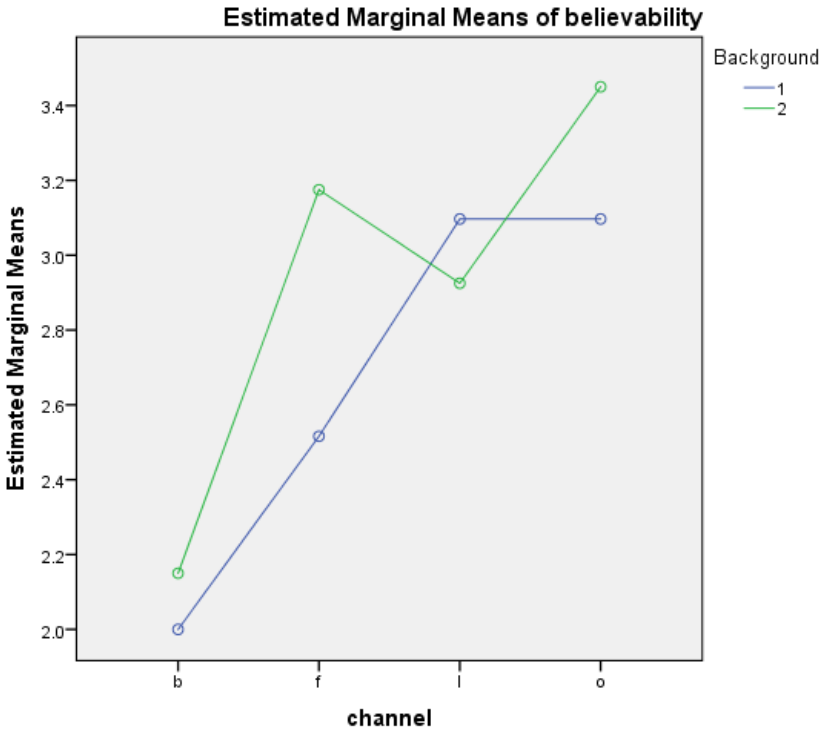

Figure 4.6. Interaction plot B for Anger

The lines (o, l) and (f, l) can be seen crossing each other (Figure 4.5). So, there is a significant interaction between the 'participant background' and the body channels 'o', 'f' and 'l'. Also, the lines for backgrounds 'CG' and 'non-CG' can be seen intersecting each other for body channels 'f' and 'l'. So, there is a significant interaction between the 'participant background' and the body channels 'o', 'f' and 'l'.

The Tukey's Post Hoc Test was done to understand the pattern in the difference of the four 'body channel' group means. The pairs 'fl' and 'lo' have a p-value of 0.876 and 0.202 respectively. Hence these two pairs are ignored for independent samples t-tests. The t-tests are performed for the other four pairs 'bf', 'bl', 'bo' and 'fo'.

Below are the hypotheses for each of the above mentioned pairs:

- H_{04}: $f - b \leq 0$
- H_{05}: $l - b \leq 0$
- H_{06}: $o - b \leq 0$
- H_{07}: $o - f \leq 0$

The p-values for the above four hypotheses were 0.000, 0.000, 0.000 and 0.007 respectively. So, all of the above four hypotheses were rejected. We can interpret from these findings that the animation ‘b’ with 50% animation toned down on the limbs, torso, neck and head is given a significantly lower rating than the other three groups. The rating for the original video is significantly higher than the video ‘f’, with facial and eyes animation toned down by 50%. The differences in rating among the groups ‘o’, ‘l’ and ‘f’, ‘l’ are not statistically significant.

4.1.4 Fear

A two-way ANOVA was performed to check the following hypotheses:

- H_{01}: Participant background has no significant effect on the believability of the animation.
- H_{02}: Body channel has no significant effect on the believability of the animation.
- H_{03}: The interaction between participant background and body channel has no significant effect on the believability of the animation.

The p-values for H_{01}, H_{02} and H_{03} are 0.065, 0.000 and 0.490 respectively. So, we reject H_{02} but we accept H_{01} and H_{03}. There is a statistically significant difference in means of the four groups that correspond to the body channels.

The Tukey’s Post Hoc Test was done to understand the pattern in the difference of the four group means. The pairs ‘lf’, ‘fo’ and ‘lo’ have p-values of 0.992, 0.166 and 0.282 respectively. Hence these three pairs were ignored for independent samples t-tests. The t-tests are performed for the other four pairs ‘bf’, ‘bl’, and ‘bo’.

Below are the hypotheses for each of the above mentioned pairs:

- H_{04}: $f - b \leq 0$
- H_{05}: $l - b \leq 0$
- H_{06}: $o - b \leq 0$

The p-values for the above three hypotheses were 0.000, 0.000 and 0.000 respectively. So, H_{04}, H_{05} and H_{06} were rejected. We can interpret from these findings that the animation ‘b’ with 50% animation toned down on the limbs, torso, neck and head is given a significantly lower rating than the other three groups. The differences in rating among the three groups ‘o’, ‘f’, ‘l’ are not statistically significant.

Table 4.10 gives the mean believability ratings for the four groups while tables 4.11 and 4.12 provide the results from ANOVA and Post Hoc tests.

Table 4.10. Means of believability ratings for Fear

Channel	Mean
b	2.06
f	2.92
l	2.96
o	3.23

Table 4.11. ANOVA results: Main and interaction effects for Fear

Source	Sum of Squares	Mean of Squares	F-value	p-value
background	2.727	2.727	3.423	0.065
Channel	53.651	17.884	22.448	0
background*channel	1.932	0.644	0.808	0.49

Table 4.12. Tukey's Post Hoc results for Fear

Channel 1	Channel 2	p-value
b	f	0
	l	0
	o	0
f	b	0
	l	0.992
	o	0.166
l	b	0
	f	0.992
	o	0.282
o	b	0
	f	0.166
	l	0.282

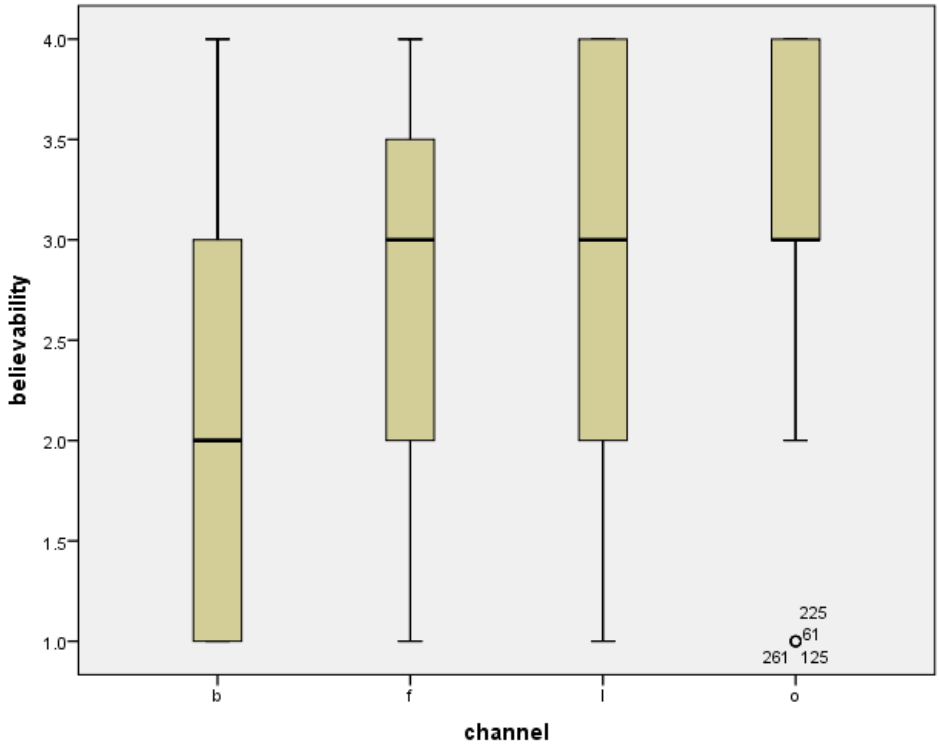

Figure 4.7. Box plot of 'participant background' for Fear

4.1.5 Surprise

A two-way ANOVA was performed to check the following hypotheses:

- H_{01}: Participant background has no significant effect on the believability of the animation.
- H_{02}: Body channel has no significant effect on the believability of the animation.
- H_{03}: The interaction between participant background and body channel has no significant effect on the believability of the animation.

The p-values for H_{01}, H_{02} and H_{03} are 0.055, 0.000 and 0.507 respectively. So, we reject H_{02} but we accept H_{01} and H_{03}. There is a statistically significant difference in means of the four groups that correspond to the body channels.

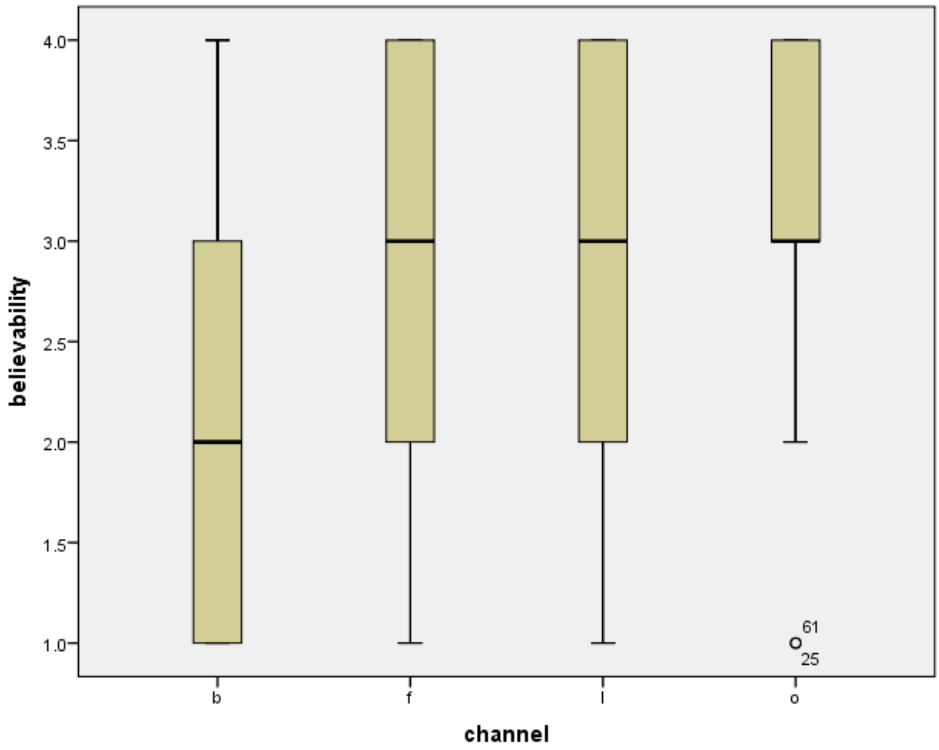

Figure 4.8. Box plot of ‘participant background’ for Surprise

The Tukey’s Post Hoc Test was done to understand the pattern in the difference of the four group means. The pairs ‘fl’ and ‘lo’ have a p-value of 0.756 and 0.322 respectively. Hence these two pairs were ignored for independent samples t-tests. The t-tests are performed for the other four pairs ‘bf’, ‘bl’, ‘bo’ and ‘fo’.

Below are the hypotheses for each of the above mentioned pairs:

- H_{04}: f – b ≤ 0
- H_{05}: l – b ≤ 0
- H_{06}: o – b ≤ 0
- H_{07}: o - f ≤ 0

The p-values for the above four hypotheses were 0.000, 0.000, 0.000 and 0.006 respectively. So, H_{04}, H_{05}, H_{06} and H_{07} were rejected. We can interpret from these findings that the animation ‘b’ with 50% animation toned down on the limbs, torso, neck and head is given a significantly lower rating than the other three groups. The rating for the original video is significantly higher than the video ‘f’, with facial and eyes animation

toned down by 50%. The differences in rating among the groups ‘o’, ‘l’ and ‘f’, ‘l’ are not statistically significant.

Table 4.13 gives the mean believability ratings for the four groups while tables 4.14 and 4.15 provide the results from ANOVA and Post Hoc tests.

Table 4.13. Means of believability ratings for Surprise

Channel	Mean
B	2.07
F	2.82
l	2.97
o	3.24

Table 4.14. ANOVA results: Main and interaction effects for Surprise

Source	Sum of Squares	Mean of Squares	F-value	p-value
background	3.245	3.245	3.718	0.055
channel	51.514	17.171	19.677	0
background*channel	2.035	0.678	0.777	0.507

Table 4.15. Tukey’s Post Hoc results for Surprise

Channel 1	Channel 2	p-value
b	f	0
	l	0
	o	0
f	b	0
	l	0.756
	o	0.037
l	b	0
	f	0.756
	o	0.322
o	b	0
	f	0.037
	l	0.322

4.2 Summary

This chapter presented the results of statistical analysis for the five emotions. Below is the summary of results for each emotion:

- Happiness: Toning down the animation of limbs, torso, neck and head caused the biggest drop of believability rating. Though the other three groups had different means (f > o > l), they are not statistically significant.
- Sadness: Though group means can be ordered as o > f > l > b, these differences are not statistically significant. It can be noted that the animation 'b' with 50% animation toned down on the limbs, torso, neck and head has the least mean.
- Anger: The main effects (background, channel) and interaction effect (background x channel) are significant. The interaction is significant between 'background' and the body channels o, f and l. Participants from non-CG background gave higher ratings than the ones with CG background. Toning down the animation of limbs, torso, neck and head caused the biggest drop of believability rating. The original animation got significantly better rating than the one with 50% facial and eyes animation. Though group means can be ordered as o > l > f > b, the mean differences in o, l and f, l are not statistically significant.
- Fear: Toning down the animation of limbs, torso, neck and head caused the biggest drop of believability rating. Though group means can be ordered as o > l > f > b, the mean differences in o, l and f are not statistically significant.
- Surprise: Toning down the animation of limbs, torso, neck and head caused the biggest drop of believability rating. The original animation got significantly better rating than the one with 50% facial and eyes animation. Though group means can be ordered as o > l> f > b, the mean differences in o, l and f, l are not statistically significant.

The next chapter talks about the conclusions arrived from the results and scope for future work.

CHAPTER 5. CONCLUSION

5.1 Animation Believability

Out of the 3 channels, it was found that the one with reduction in body motion received the least rating for the emotions happiness, anger, fear and surprise. Sadness seems to be an exception as the differences are not significant. This can be attributed to the fact that an action feels sadder if the motion is reduced. Hence the reduction of body movement by 50% enhanced the believability of sadness for most participants.

The insignificant difference in rating among the toning down of face/eyes, lip sync and the original animation among all the groups show that the lack of facial, eyes and lip sync animation does not diminish the believability as much as the lack of body motion does.

Though main effects of the two independent variables 'participant background' and 'body channel' are significant for all the five emotions, only anger seem to have a significant interaction effect. Participants from non-CG background gave higher ratings than the ones with CG background for the anger emotion.

To generalize, when it comes to a stylized character animation in a full body shot using a male character, it does appear that biggest contributor to the believability is the body motion while it appears that the reduction in facial and lip sync animation does not impact the believability as much as the reduction in body motion.

5.2 Future Work

Though body motion was found to be significantly more important than face, eyes or lip sync, there was no significant difference in rating found among the animations of face, eyes or lip sync. It will be interesting to see how these three channels differ in importance in a medium shot.

Also, sadness came out as an exception in this research. Though reduction in body motion caused the biggest dip in the ratings for the rest of the emotions, it increased the believability of sadness. However it is not statistically significant. Future work can focus

on the interplay of different body channels in the believability of sadness with statistical significance.

Participant background seems to impact ratings only for the emotion - anger. Participants with non-CG background seem to rate the animations higher than the ones with CG background. It is worth investigating if this is a norm across animation ratings in general.

Though the rig used for this research is a stylized rig, the body proportions are close to realistic human proportions. It will be interesting to see if the results from this research apply to more exaggerated body proportions.

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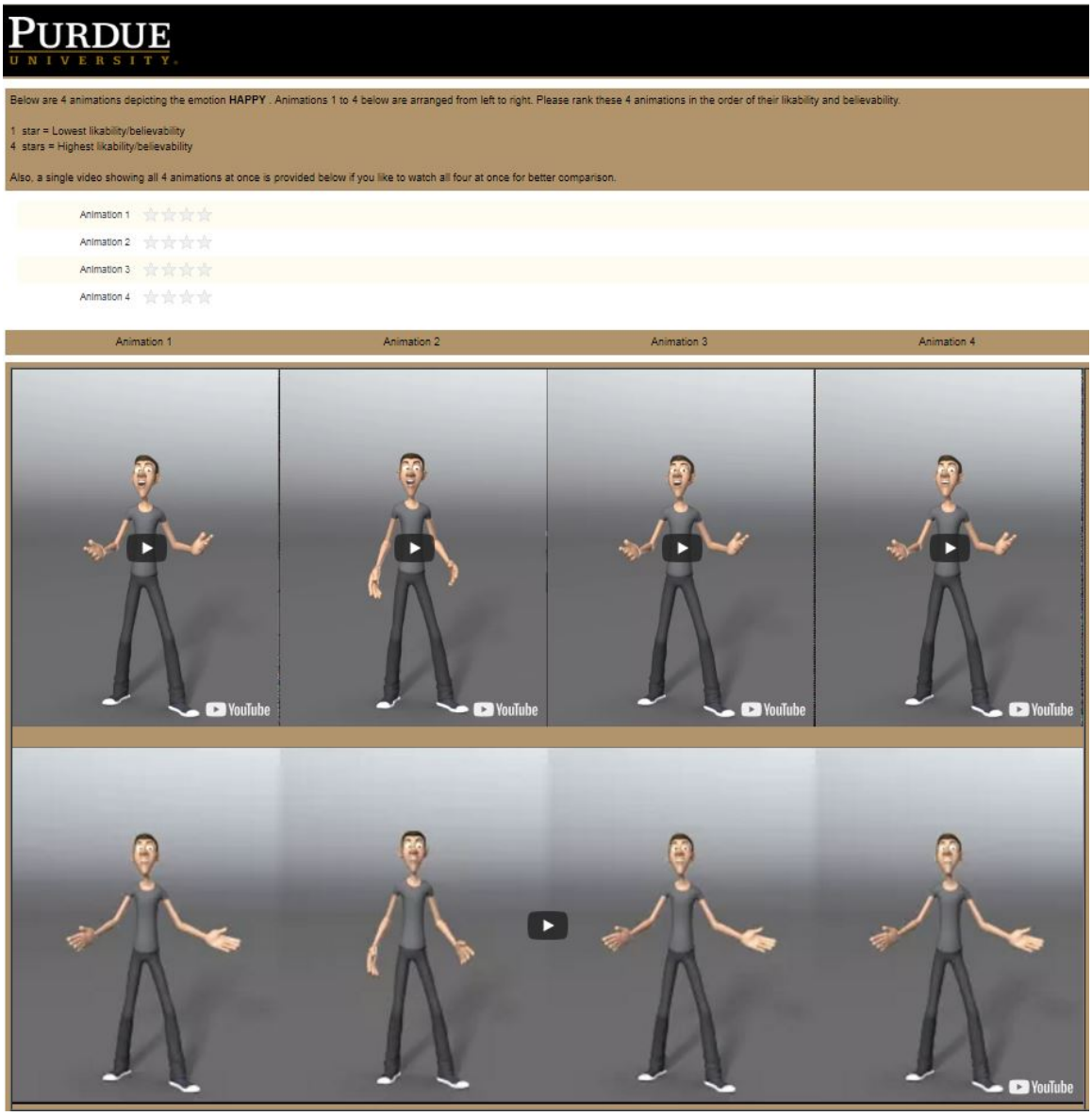
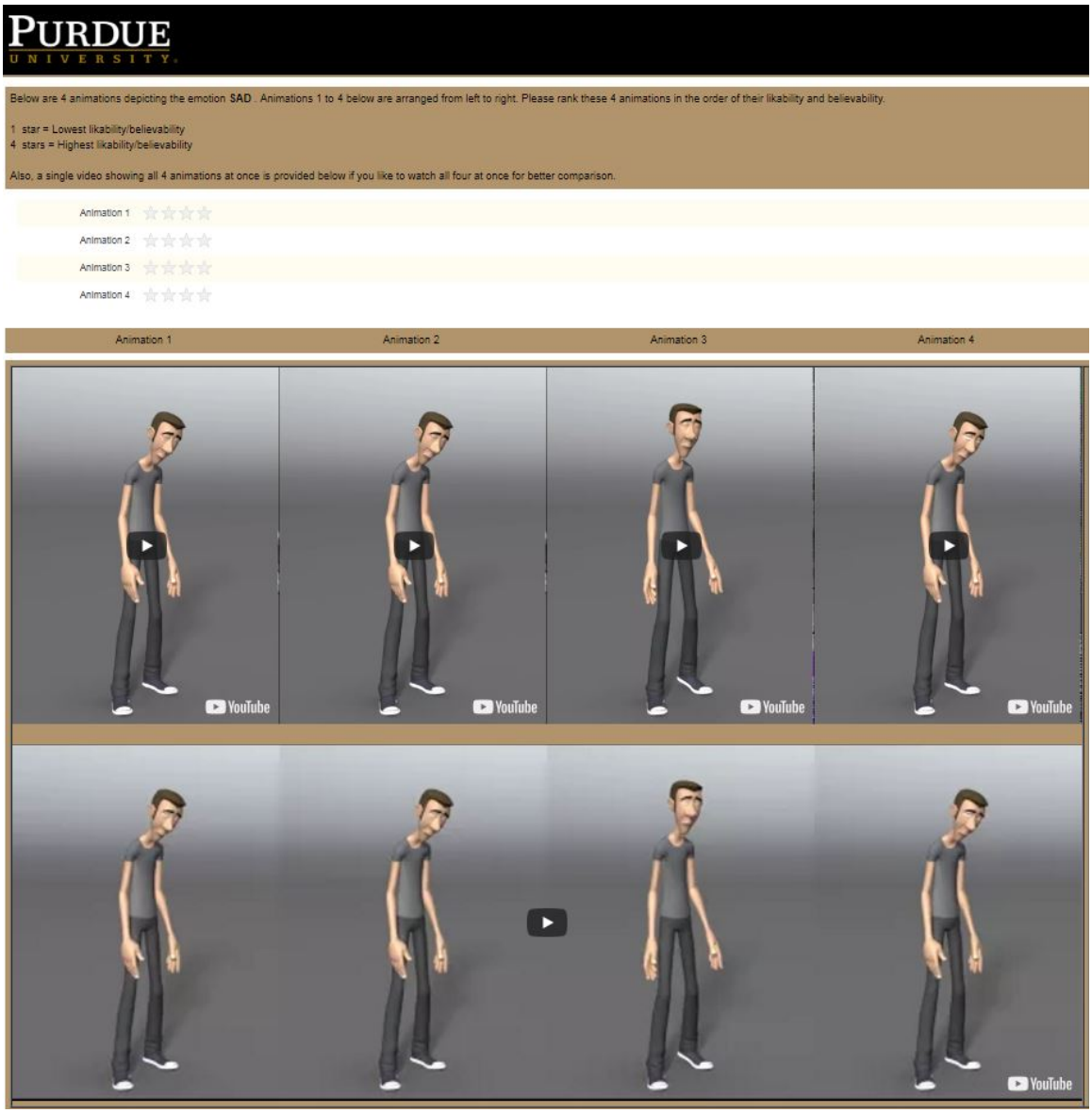
APPENDIX A. EVALUATIVE SURVEY

The following are the screenshots of the main questions for each of the five emotions from the survey.

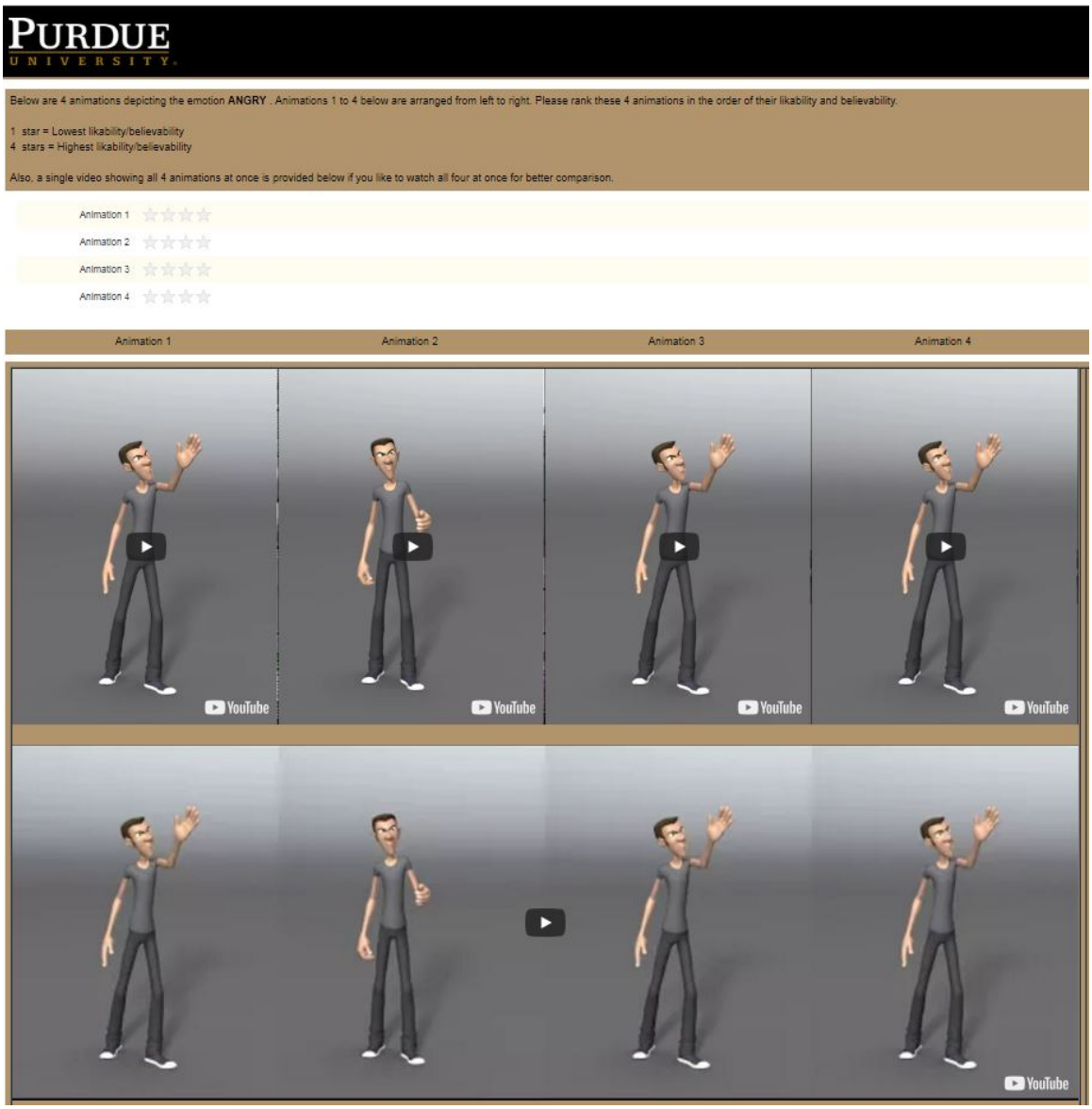
HAPPINESS



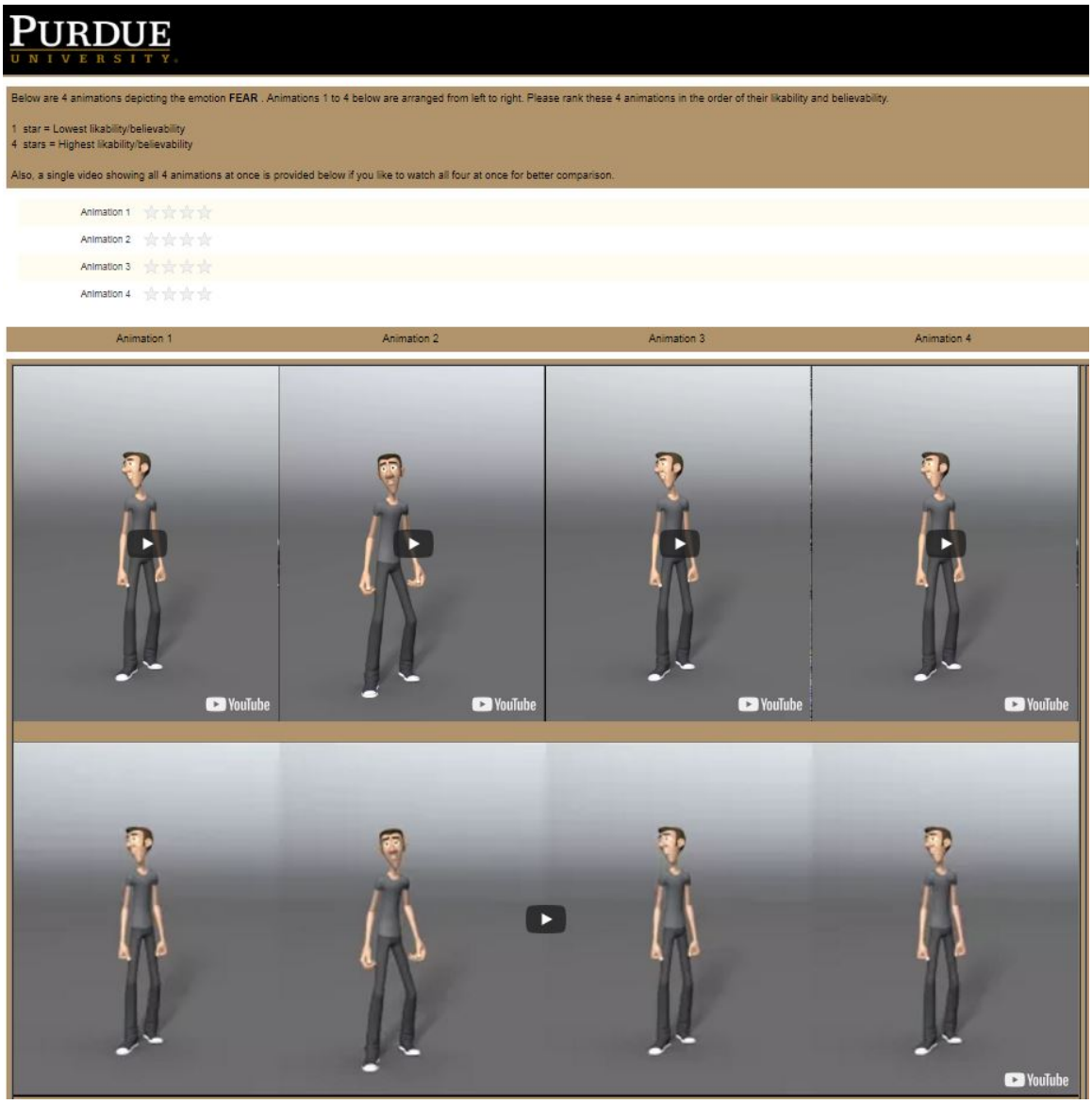
SADNESS


PURDUE
UNIVERSITY
Below are 4 animations depicting the emotion SAD . Animations 1 to 4 below are arranged from left to right. Please rank these 4 animations in the order of their likability and believability.
1 star = Lowest likability/believability
4 stars = Highest likability/believability
Also, a single video showing all 4 animations at once is provided below if you like to watch all four at once for better comparison.
Animation 1
Animation 2
Animation 3
Animation 4
Animation 1
Animation 2
Animation 3
Animation 4
YouTube
YouTube
YouTube
YouTube
YouTube

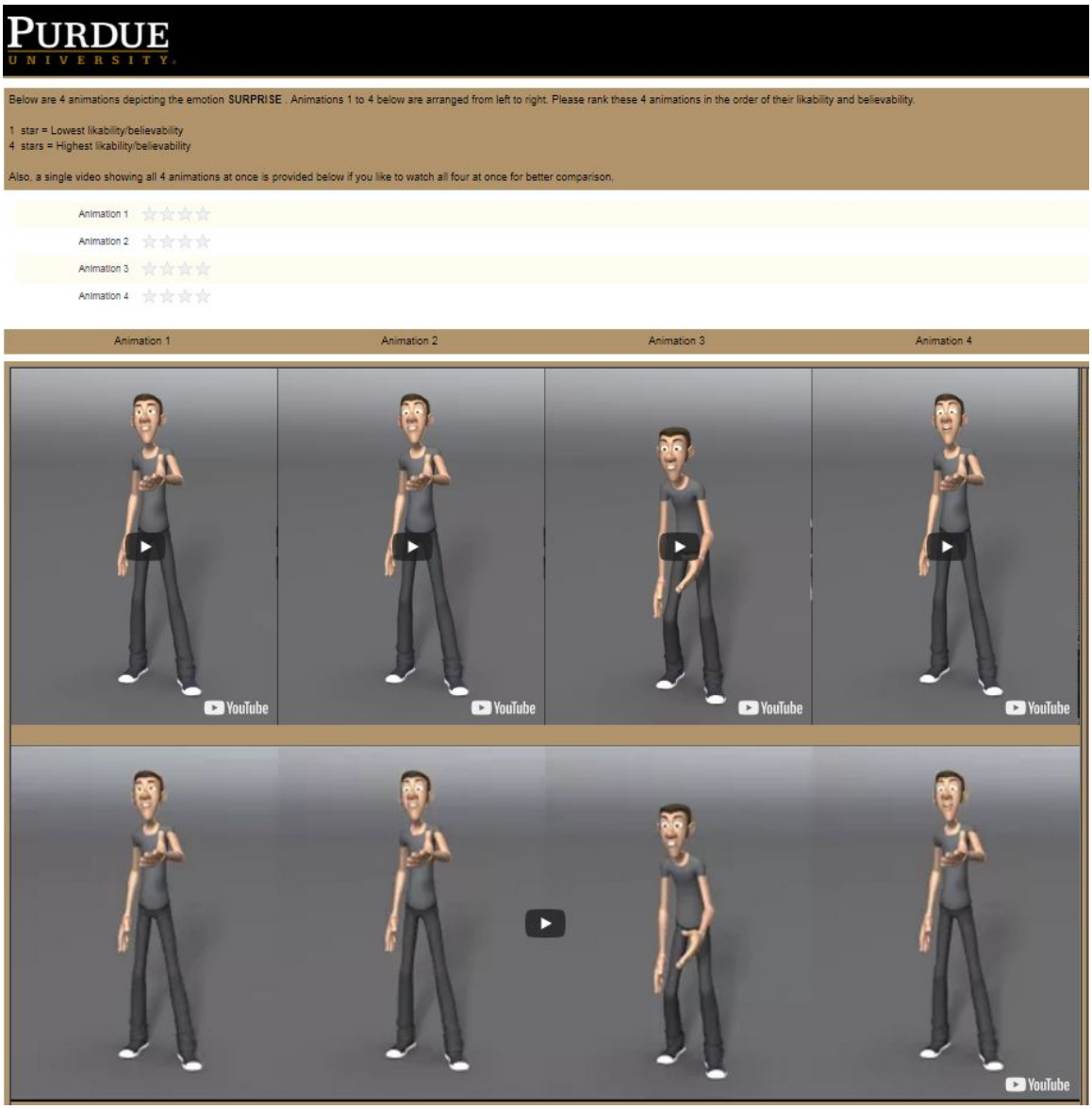
ANGER


PURDUE
UNIVERSITY
Below are 4 animations depicting the emotion ANGRY . Animations 1 to 4 below are arranged from left to right. Please rank these 4 animations in the order of their likability and believability.
1 star = Lowest likability/believability
4 stars = Highest likability/believability
Also, a single video showing all 4 animations at once is provided below if you like to watch all four at once for better comparison.
Animation 1
Animation 2
Animation 3
Animation 4
Animation 1
Animation 2
Animation 3
Animation 4
YouTube
YouTube
YouTube
YouTube
YouTube

FEAR


PURDUE
UNIVERSITY
Below are 4 animations depicting the emotion FEAR . Animations 1 to 4 below are arranged from left to right. Please rank these 4 animations in the order of their likability and believability.
1 star = Lowest likability/believability
4 stars = Highest likability/believability
Also, a single video showing all 4 animations at once is provided below if you like to watch all four at once for better comparison.
Animation 1
Animation 2
Animation 3
Animation 4
Animation 1
Animation 2
Animation 3
Animation 4
YouTube
YouTube
YouTube
YouTube
YouTube

SURPRISE


PURDUE
UNIVERSITY
Below are 4 animations depicting the emotion SURPRISE . Animations 1 to 4 below are arranged from left to right. Please rank these 4 animations in the order of their likability and believability.
1 star = Lowest likability/believability
4 stars = Highest likability/believability
Also, a single video showing all 4 animations at once is provided below if you like to watch all four at once for better comparison.
Animation 1
Animation 2
Animation 3
Animation 4
Animation 1
Animation 2
Animation 3
Animation 4
YouTube
YouTube
YouTube
YouTube
YouTube

APPENDIX B: SURVEY DATA

The following table provides the data collected for each of the five emotions.

happiness				sadness				anger				fear				surprise			
o	b	f	l	o	b	f	l	o	b	f	l	o	b	f	l	o	b	f	l
2	3	2	2	2	3	2	2	3	2	1	3	3	2	3	3	3	3	2	3
4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4	4	2	4	4
3	2	3	3	4	2	4	3	4	2	3	3	3	2	3	2	4	3	2	3
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1	4	3	2	1	3	4	2	2	1	3	4	4	1	3	2	4	1	2	3
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