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ABSTRACT

Superhuman sports (SHS) is a field where technological augmentations of human abilities and environment are combined to play a new and exciting sport. SHS make use of artificial senses or virtual reality to create a new experience that involves physical fitness and skills. *Star Tag* aims to combine these aspects with an engaging audience experience. This augmented reality game uses the Microsoft HoloLens, making it possible to move through a mixed reality space effectively. *Star Tag* is a competitive multiplayer game where players need to conquer all planets from their opponent to win the game. Players need to move around in a physical space from virtual planet to virtual planet in order to navigate the game-space and reach the planets. The audience is involved with the game via their phones, through which they can support the players. Through playtesting and conducting a survey, the results show that *Star Tag* is a superhuman sport that motivates people to be physically active.

Index Terms: Human-centered computing—Mixed / augmented reality Human-centered computing—User studies Human-centered computing—User interface design Software and its engineering—Interactive games

1 INTRODUCTION

Superhuman sports attempt to combine technological human augmentations with sports, focusing on overcoming physical and psychological limitations of humans with artificial senses and capabilities [1]. They may also focus on aspects other than augmenting the players' capabilities, such as enhancing the playing field or enabling interactions with spectators. This can be achieved in two main ways: technology can be used to physically enhance humans, or a virtual world can be created with which the players can interact. When looking at virtual augmentations, the space that the players interact with can be defined as a continuous spectrum. On one side of the spectrum there is the completely real world and on the other side there is the completely virtual world [2]. In the middle of this spectrum, we find mixed reality (MR), which merges the real world with virtual augmentations to create an MR world. In this world, real and virtual objects co-exist and can interact with each other [2]. The significance of augmented reality is that it combines immersive digital components with a person's perception of the real world, and creates the sensation that they are part of the same environment. There are multiple ways in which this hybrid world can be displayed. One immersive approach is to use head-mounted devices. Other methods use one or more phones, where the camera feed is displayed on the screen of the phone and virtual objects are overlaid on that screen. Combining elements of the real and virtual world, MR creates an environment that is suitable for superhuman sports.

One device for displaying augmented reality is the Microsoft HoloLens. This is a head-mounted unit fitted with a clear pane through which a user can view the real world [3]. On this pane, holograms are projected to incorporate virtual objects with the real world. The device is wireless and allows a user to move freely without the danger of hurting themselves as a result of an obstructed view, which is the case with most virtual reality (VR) glasses. By moving freely, while still being aware of the real physical space, the HoloLens affords active movement while playing video games. The goal of this research is to determine if a mixed reality game can encourage active playing, as well as if the audience can be engaged to complement players' actions.

To validate our goal, *Star Tag* was developed. In the following sections, this paper analyzes existing research on superhuman sports. Next, the *Star Tag* game design and first results of a user study are presented. The paper concludes by discussing the results and giving an outlook on future work.

2 RELATED WORK

Recently, different superhuman sports using the HoloLens were developed. *STAR* (Superhuman Training in Augmented Reality) [4] is a survival game where one or two players have to navigate a virtual maze path while avoiding enemies. The levels contain enemies that can be killed by shooting at them with light beams, which adds a superhuman impression to the game. Another example of a superhuman sport is *League of Lasers* [5], which requires players to move around the playing field in order to deflect a virtual laser pulse into the opponent's goal. Both *STAR* and *League of Lasers* motivate the player to be physically active during gameplay. However, they do not have an active audience interaction, as they were designed for single or cooperative play modes and passive spectator viewing.

In addition, *Hado* [6] is a relatively popular superhuman sport that uses augmented reality in a competitive setting. It was created by Meleap Inc. and has become a professional sport in Japan for which tournaments with significant prize pools are organized[1]. The game has similar characteristics to dodgeball but replaces the ball with a virtual object. This object is a superhuman energy ball that players can throw at each other. *Hado* uses self-made augmented reality gadgets that use smartphones and sensors for gestures. Through this, players are encouraged to get physically active as they are required to continuously move around in order to win.

Likewise, *Capture the Flag* is an augmented reality game with multiple players. It is, however, different from the aforementioned examples. It uses a large-sized tablet and multiple phones to allow users to interact with each other [7]. While moving their phones over the tablet's surface, players can see their private information in augmented reality, which they can use to capture other players' flags. Through the competitiveness of the game, *Capture the Flag* motivates players to interact with each other.

Pokémon Go is an active game that is effective in stimulating physical activity that was able to reach a large user-group [8]. It is a mobile game that allows the player to navigate the real world and catch fictional characters called Pokémon, or battle with other players at various physical locations. This game aims to motivate players to go outside and be active.

Lastly, an example of a sport with an involved audience is soccer. Soccer fans are dedicated to their teams and being a member of a

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[1] http://meleap.com/tournament/

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fan-group forms a part of their identity and influences their emotions positively. This is one of the reasons why it is such a popular sport [9]. Despite the lack of augmented elements, soccer is a highly active sport that is played on a professional level and has a devoted fan-base.

The use of the HoloLens in *League of Lasers* and *STAR* is effective in making players more immersed and more active during gameplay. *Hado*, *Pokémon Go* and soccer have a substantial player-base which is one of the reasons that makes them appealing. Likewise, some of these games have an involved audience which makes the game more attractive as well. Finally, an inspiring aspect of *Capture the Flag* is that the game is played with multiple devices which also show the game's progress. Using an additional device with the HoloLens to view the game could make the audience feel more engaged.

The several sports and video game aspects shared with superhuman sports, such as activity, augmentation and audience involvement, inspired the design of *Star Tag*, which is presented in the following section.

3 Game Design

Star Tag is a competitive superhuman sport that is set in a mixed reality space created for the Microsoft HoloLens. As the name suggests, *Star Tag* has a space theme wherein two players compete to conquer each other's planets, in order to dominate the galaxy. For their virtual 'interplanetary trips', the players can walk or run around the game-field, and use the HoloLens clicker to interact with virtual objects. The two players are joined by an audience that can actively contribute to the gameplay (see Section 3.3).

3.1 Gameplay

Star Tag starts with two players on opposite sides of the playing field, next to their home planet, each with its own color (blue or red). To be able to view the planets and to track the whereabouts of the players, both players wear a HoloLens. In addition to the two home planets, there are a number of neutral planets on the playing field. These planets start with a grey (neutral) color to indicate that they have not been obtained by either player. The playing field is currently 11 meters long and 5.5 meters wide and contains a total of 13 planets including the already colored home planets. All planets have and generate energy, which players can obtain as a form of currency that they can use to conquer other planets. The goal of the game is to capture all planets, and both players strive to achieve that by strategically distributing the energy of their own planets and transporting it to the opponent's planets.

Each neutral planet starts with less energy than the home planets, which has to be depleted in order to be conquered. This allows the players to immediately start capturing planets when the match begins. Initially, the home planets are the players' only energy source until they conquer new planets; subsequently, by collecting energy from any of their planets, players can use it to either take over neutral planets or steal planets from the opponent. To keep the game fair, players and the environment are symmetrically balanced at the beginning of the match.

When a planet is conquered, its color changes to the player's respective color and starts to generate energy at a constant rate. As a result, planets that belong to a player have an increasingly higher energy level over time. It is up to the player to either collect energy from their planets to conquer more, or to deposit additional energy to them to prevent them from being easily taken over by the opponent.

As the energy transfer process takes up some time, a player should not spend much time moving from one planet to the next, as the opponent might take over more planets during that time. Therefore, players need to run from planet to planet in order to prevent losing planets by wasting time. Also, by strategically choosing which planets to conquer, a player can make it more difficult for the opponent to steal their planets. By moving fast and by choosing an effective strategy for the distribution of their energy, a player can conquer all planets before their opponent does, and consequently win the game.

3.2 Game Controls

Both players wear a HoloLens that displays a number of planets that are distributed across the playing field, as shown in Figure 1. The larger the playing field, the more planets can be generated in the game. After navigating to a planet's location, players can perform two types of actions: (i) *collect* energy from their own planets, and (ii) *deposit* energy to a planet in order to either deplete the energy level and attempt to capture it (if it is neutral or hostile), or to increase its energy level (if it is theirs), see Figure 2. These interactions are initiated by using the HoloLens clicker to toggle between deposit and collect modes. While standing near the planet, players can press and hold the button on the clicker to transfer the energy. The longer the button is pressed, the more energy is transferred. This enables the player to accurately control the amount of energy that is transferred.

If a player transfers energy to a neutral or hostile planet, first that planet's energy level is depleted with the player's deposited energy. As soon as the planet's energy level reaches zero, it is conquered and the energy level starts increasing until the transfer is stopped (or the player runs out of energy). It is possible for two players to transfer energy to one planet at the same time, but eventually, the player who transfers the largest amount of energy conquers the planet.

3.3 Audience Participation

In addition to being an augmented and physically active game, *Star Tag* also includes a mechanism to directly involve the audience. This aims at creating a sense of competition and engagement, similar to how audience involvement boosts the popularity of soccer. This could contribute to the potential popularity of *Star Tag*, as the audi-

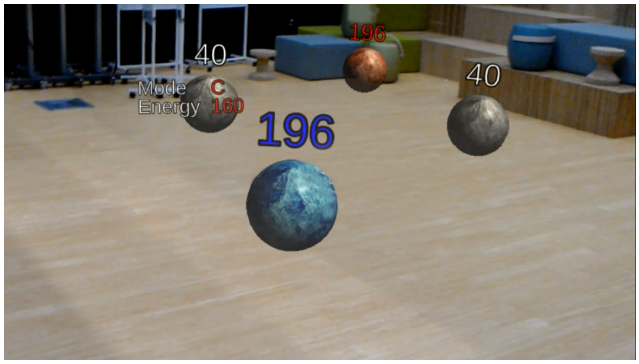

Figure 1: Player view of planets through the HoloLens

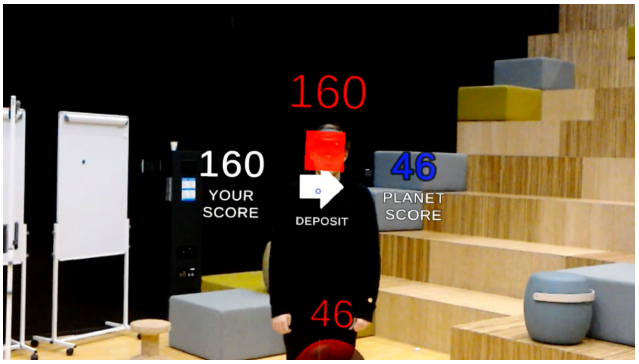

Figure 2: Player view through the HoloLens while depositing energy

Figure 3: Audience view set-up with a large screen above the players

Figure 4: Current mobile user interface for audience participation

ence directly participates in the game and has a connection to the players.

The audience can follow the progress of the game on a large projection screen, as shown in Figure 3. This overview depicts the playing field from a top view, showing both the location and the energy levels of the players and planets.

Star Tag audience members are also split into two groups and each member is assigned to one of the players' teams, through a web page on their mobile phone. Both teams compete to support their respective player. There exist multiple audience events that can occur during the game. On their phones, each team of audience members receives three possible actions to take, randomly selected from a larger pool of options. When a majority has voted for a certain option, the action is activated. After that, the team has a cool-down period before it can vote for a new action. Audience members are not required to connect through the web page to spectate the game. Figure 4 shows the current mobile user interface with an example of three actions the audience can choose from.

4 Implementation and Design Choices

Star Tag is developed with Unity Engine[2], a game creation platform, and is written in C#. The open-source Mixed Reality Toolkit for Unity [10] was used for assets and utility functions. The web server that is used for the audience participation system uses NodeJS[3].

4.1 Mechanics

For a fair game, all game object positions and their properties have to be equal for all players. In order to be able to play *Star Tag* with two players, a way of sharing this spatial data is needed. World anchors are used to keep the positional data of game objects identical for both players. A world anchor is responsible for sharing the information of virtual objects in relation to the real environment with all players in the game.

[2]https://unity3d.com
[3]https://nodejs.org

Furthermore, it is necessary to determine a clear way for the player to differentiate between collecting and depositing energy. The players need to be able to define what action they want to perform with regards to a planet without any confusion or ambiguity. The HoloLens supports voice and gesture commands, but these can be unreliable in combination with the activeness of the game. In the case of voice commands, the HoloLens might respond to the opponent's commands when the players are near each other. Additionally, as the player is actively moving around, it can be difficult to make coherent gestures that the HoloLens is able to detect. Therefore, the player can switch between collecting and depositing energy by clicking the button on the HoloLens clicker. This device is small and can be used with one hand. It does not restrict the mobility of the player and allows for a fast-paced game.

Likewise, it is important to define the exact method for interaction between a player and a planet. The planets are represented by spheres that are positioned in the playing field around eye-level. The player needs to be in the same location as the planet to be able to transfer energy. The game determines the location of the player in a two-dimensional manner: the height of the player is ignored. This, in turn, allows the audience view to be a top-down view of the playing field. Moreover, due to the use of this mechanism, shorter players do not have a disadvantage over taller players or vice versa.

4.2 Visibility

The area in which the HoloLens shows the holograms is smaller than an average person's field of vision which forms a hindrance for its applications. It can be described as a window or screen through which the augmentation is visible. For this reason, *Star Tag* does not have fast-moving objects, as the limited field of vision would make it difficult for the player to keep track of them. Similarly, there are no overly large objects in the game, since it is difficult to get a wide view of the environment through the HoloLens.

5 User Study

Star Tag aims to promote physical activity through competitive gaming, hence it targets people who enjoy playing video games, or

Session nr.	Time	Player 1		Player 2	
		Total steps	**Step rate p. minute**	**Total steps**	**Step rate p. minute**
1	5m10s	274	53	183	35.4
2	5m20s	45	8.4	205	38.4
3	6m	191	32.7	116	28.5
4	5m	118	23.6	106	21.2
5	3m30s	175	50	147	42
Average	5m	**Total steps**: 156		**Step rate p. minute**: 33.3	

Table 1: Step count of Star Tag players

who like to watch other people play video games through online streaming. Both of these cases are examples of inactive screen-time, which result in a lack of physical exercise in the aforementioned people's lives. To appeal to this group, *Star Tag* was designed to have an intriguing superhuman theme and gameplay that is engaging for the players as well as for the audience. The game is created in such a way that it is easy to comprehend for inexperienced gamers as well. In this user study, we report on initial experiences with regards to the activity and enjoyment of playing *Star Tag*.

5.1 Participants

In order to get participants for *Star Tag*, twelve people were randomly recruited in a university building to try out the game. Ten participants were university students, the other two participants were university employees. None of the participants had prior experience with using the HoloLens.

5.2 Method

To meet the public health guidelines, an average adult should take at least 8000-10,000 steps per day, of which 3000 steps should be at moderate intensity [11]. As the basic level of physical activity varies for different people, the public health guidelines recommend encouraging people to increase their step count with 3,000 to 4,000 extra steps per day [12]. According to these guidelines, people should walk more on at least five days of the week to increase their physical activity. In order to reach both of these goals, it would be helpful if people could engage in activity that stimulates them to walk more. Therefore, to evaluate the efficacy of *Star Tag* on physical activity, we examine the number of steps a person takes while playing an average game.

To determine the number of steps people take while playing *Star Tag*, we attached a step counter to each participant's pants pocket or shoe. We attached the step counter in two places to control the outcome of both methods. The step counters used in this study were basic models with a mechanical switch that counts the steps. Each test session was timed and stopped after 3 to 6 minutes. During normal circumstances, when the game stops after a player wins, the sessions would take longer. The step rate of each player was calculated by dividing the numbers of steps by the time of the session they played.

Furthermore, players should feel motivated to be active during the game in order for *Star Tag* to be effective in stimulating physical activity. To measure this, every participant was asked to fill in a questionnaire after playing the game (Table 2). Our questionnaire focused on the self-reported physical activity of our participants and their enjoyment of the game after they had finished. Each participant answered each question on a five-point Likert scale [13]. For additional feedback, a few unstructured interviews were conducted as well.

5.3 Results

In total, six sessions took place with a total of twelve participants (two players per session). One session produced inaccurately low results as a result of the HoloLenses malfunctioning. Consequently, the participants were not able to correctly play the game. For this reason, the data from this session was excluded.

The results from five sessions are presented in Table 1. During the first three sessions, the step counter was clipped to the participant's pants pocket and during session 4 and 5 it was clipped on one shoe. As the results from both methods are similar, it seems like we do not have to make a distinction between the two in our results. The average game play time for each of the five sessions is around five minutes, with an average step count of 156 steps per person, at an average rate of 33.3 steps per minute.

Most of the Likert scale questions were answered positively (Table 2 and Figure 5). The statement most people agreed with was *H. Playing a game on the HoloLens was exciting*. The statement the least people agreed with was *D. I would have been better at the game if I had run faster*. Overall, most participants felt involved and enjoyed the physical activity in the game.

5.4 Discussion

During the playtesting sessions it became clear that people required some time to get used to the HoloLens and the controls of *Star Tag*. None of the participants had prior experience with using a HoloLens, which resulted in the game sessions being rather slow-paced because the players often stood still instead of walking around. On the other hand, most people seemed to understand the game mechanics after a few minutes of play. We hypothesize that people with experience feel more comfortable with the HoloLens and walk more during the game and at a faster pace. Therefore, players are probably more active when having played *Star Tag* more than once, resulting in a higher step count.

In future test sessions, we propose to first have a trial session before an evaluation session. This way, the participants can get used to the HoloLens and the mechanics of the game. Then, when the actual session starts, they are able to spend all the time on trying to win, which might increase the step count.

Nevertheless, even inexperienced players took, on average, 33 steps per minute. So, if *Star Tag* is played for 30 minutes a day, players would approximately take an additional 1000 steps a day. This number would increase with more experienced players and when the game is played for longer periods of time or on a larger playing field. This shows that *Star Tag* could make a significant contribution to people taking the recommended 3,000 to 4,000 additional steps per day.

6 Conclusion

Star Tag is a superhuman sport designed for the HoloLens, in which two players compete to conquer all planets in the playing field. During the game, the audience is actively participating and influencing the game in real-time.

During development, several design choices were made. Firstly, to properly position all game objects in the MR world, a world anchor was used to pin the HoloLens' spatial mapping to the true environment. Secondly, key game-play design choices were made regarding the collecting and depositing actions, by means of the HoloLens clicker. Additionally, through testing *Star Tag* with both a

Questions	Strongly Disagree - 1	Disagree - 2	Neutral - 3	Agree - 4	Strongly Agree - 5	Average score
Level of effort as a player						
A. I tried my best during the game	0%	8%	8%	42%	42%	4,2
B. I needed to be active to try and win the game	0%	8%	50%	42%	0%	3,3
C. I tried to be faster than my opponent	0%	0%	25%	50%	25%	4,0
D. I would have been better at the game if I had run faster	25%	8%	42%	25%	0%	2,7
E. I didn't mind to walk and run during the game	0%	17%	8%	33%	42%	4,0
About the game						
F. I felt motivated to be active during the game	0%	17%	17%	50%	17%	3,7
G. I would like to play Star Tag more than once	0%	8%	0%	75%	17%	4,0
H. Playing a game on the HoloLens was exciting	0%	0%	8%	42%	50%	4,4
I. I felt involved in the game	0%	0%	17%	42%	42%	4,3
J. The game was fun to play	0%	8%	0%	67%	25%	4,1

Table 2: Results of the player questionnaire

step counter and a questionnaire, it can be concluded that the players were rather involved in the game and felt motivated to move around. Furthermore, even first-time players took roughly 1000 steps in 30 minutes, which is quite an achievement.

Since *Star Tag* was only tested for how active the participants were during the game, we plan to analyze other aspects, such as motivation or the impact of augmented reality on the players. Notably, it would be interesting to research the psychological factors of motivation to play video games in comparison to *Star Tag*. Furthermore, the audience participation was not evaluated during the initial testing. Thus, we have planned further testing to get a better understanding of the audience's engagement in the game and to determine whether they feel motivated to play the game as well.

In a future update of *Star Tag*, we plan to add support for teams of two or more players. Adding such a collaborative element to the game might make the game more engaging to watch and ask for different strategies as compared to the current version. Secondly, implementing a 3D playing field could make the game more physically active. In this case, players would have to find ways for reaching certain planets by climbing objects or lifting each other. Additionally, having the players toggle between deposit and collect mode by squatting or jumping could increase the activity of the game. Moreover, this might be a more intuitive way of controlling this game mechanic, but this needs to be tested first. Lastly, we plan to more thoroughly evaluate the effect of human augmentation on physical activity by conducting playtests with a larger user group and playing field. To identify how far human augmentation contributes to the activity and engagement, we plan to compare *Star Tag* with a non-AR version of the game.

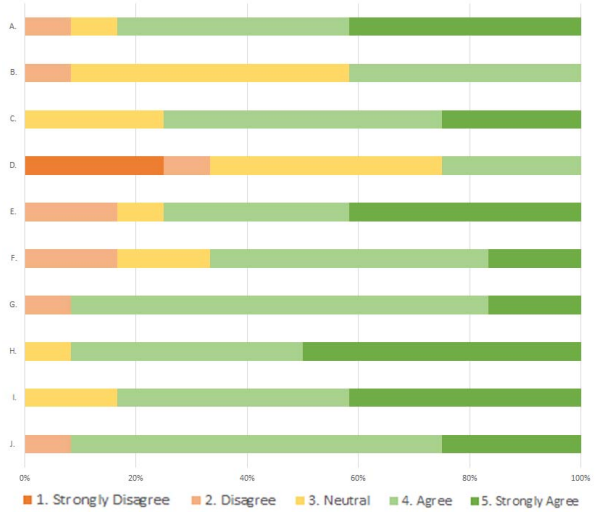

Figure 5: Visualization of the questionnaire results (Table 2)

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References

[1] K. Kunze, K. Minamizawa, S. Lukosch, M. Inami, and J. Rekimoto. Superhuman sports: Applying human augmentation to physical exercise. *IEEE Pervasive Computing*, 16(2):14–17, 2017.

[2] Paul Milgram and Fumio Kishino. A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12):1321–1329, 1994.

[3] Microsoft. Microsoft HoloLens. Accessed: 2018-11-19.

[4] Marie Kegeleers, Shivam Miglani, Gijs MW Reichert, Nestor Z Salamon, J Timothy Balint, Stephan G Lukosch, and Rafael Bidarra. Star: superhuman training in augmented reality. In *Proceedings of the First Superhuman Sports Design Challenge: First International Symposium on Amplifying Capabilities and Competing in Mixed Realities*, 2018.

[5] Jop Vermeer, Shaad Alaka, Niels de Bruin, Nico Arjen Miedema, Nick Winnubst, Cyril Trap, and Rafael Bidarra. League of lasers: A superhuman sport using motion tracking. *Proceedings of Superhuman Sports Design Challenge: First International Symposium on Amplifying Capabilities and Competing in Mixed Realities*, Jul 2018.

[6] meleap Inc. Hado. Accessed: 2018-11-19.

[7] Suzanne Mueller, Andreas Dippon, and Gudrun Klinker. Capture the flag: Engaging in a multi-device augmented reality game. In *Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces*, ITS '15, pages 277–282, 2015.

[8] T. Althoff, R. W. White, and E. Horvitz. Influence of pokemon go on physical activity: Study and implications. *Journal of medical Internet research*, 18(12), 2016.

[9] Richard J. Crisp, Sarah Heuston, Matthew J. Farr, and Rhiannon N. Turner. Seeing red or feeling blue: Differentiated intergroup emotions and ingroup identification in soccer fans. *Group Processes & Intergroup Relations*, 10(1):9–26, 2007.

[10] Microsoft. Mixed Reality Toolkit for Unity. `https://github.com/Microsoft/MixedRealityToolkit-Unity`. Accessed: 2018-11-19.

[11] Catrine Tudor-Locke. Steps to better cardiovascular health: How many steps does it take to achieve good health and how confident are we in this number? *Current Cardiovascular Risk Reports*, 4(4):271–276, Jul 2010.

[12] Simon J. Marshall, Susan S. Levy, Catrine E. Tudor-Locke, Fred W. Kolkhorst, Karen M. Wooten, Ming Ji, Caroline A. Macera, and Barbara E. Ainsworth. Translating physical activity recommendations into a pedometer-based step goal: 3000 steps in 30 minutes. *American Journal of Preventive Medicine*, 36(5):410 – 415, 2009.

[13] Ankur Joshi, Saket Kale, Satish Chandel, and Dinesh Pal. Likert scale: Explored and explained. *British Journal of Applied Science & Technology*, 7:396–403, 2015.