Usability of Different Types of Commercial Selfie Sticks

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ABSTRACT
This paper reviews and categorizes the most common types of selfie sticks available in the market and discusses their design and usability. Through a theoretical analysis, it demonstrates how most commercial selfie sticks ignore important human factors, including ergonomics. It, then, presents results of an online survey, where selfie stick users (N=105), predominantly from the Republic of Korea, rated the usability of their selfie sticks. Results of the survey provided an insight into users' selfie stick usage behavior and suggested that most commercial selfie sticks are unergonomic, causing the users short-term fatigues that could "in theory" turn into chronic over the time with extensive use. Finally, based on the survey results, the paper makes recommendations for future design.

Author Keywords
Selfie stick; evaluation; design; ergonomics; usability; self-photography; camera; smartphone; mobile device.

ACM Classification Keywords
H.1.2. Models and Principles: User/Machine Systems; B.4.m. Input/output and Data Communications: Miscellaneous.

INTRODUCTION
Selfie sticks are becoming increasingly popular among young smartphone users [20]. A recent survey involving 18-34 years old mobile users in the U.S. revealed that about 95% of them have taken at least one selfie, and about 27% of them have used a selfie stick [5]. Industries, including major smartphone manufactures like OPPO [21], are attempting to capitalize on this by designing new and improved selfie sticks.

However, using a selfie stick could be physically demanding. Not only it requires carrying a smartphone or camera attached monopod around but also adjusting the angle and balancing the selfie stick with one hand for the intended view is often difficult. Therefore, it is essential that new selfie sticks are designed with due consideration of human factors. Yet to our knowledge, no prior work has explored the usability of the commonly used selfie sticks. This paper attempts to address this by categorizing, and evaluating the usability of different types of commercial selfie sticks.

We used a simplistic approach for our investigation. First, we identified the most common types of selfie sticks through an informal survey of the most popular online shopping websites, specifically Alibaba, Amazon, and eBay. Then, we categorized the selfie sticks based on their features, and discussed their design and usability. Finally, we conducted an online survey where selfie stick users, predominantly from the Republic of Korea, rated and commented on the usability of their selfie sticks.

RELATED WORK
Several recent studies have investigated if taking selfies and using selfie sticks makes users more prone to accidents. In a survey, Flaherty and Choi [9] identified numerous traumatic injuries associated with these activities. They concluded that *"the lack of situational awareness and temporary distraction inherent in selfie-taking"* exposes users to potential hazards, including falls from steps, pedestrian injuries, and road traffic accidents. Similarly, Howes [13] investigated how spectator selfies increase the number of incidents, injuries, and near-misses in outdoor sports, such as marathons and road cycling.

Svelander and Wiberg [19] argued that the practice of selfies is not a purely individual act or an expression of narcissism, but a sociomaterial practice that should be studied by keeping *"one keen eye on how technologies and social media platforms are developing, and another one on the characteristics surrounding this practice"*. Some have also investigated the influence of selfie and selfie sticks on human behavior and personality [4,8,17,18], society [15], social network [12], and journalism [16].

A different set of research has proposed alternative usage of selfie sticks. For example, Criscito and Stein [7] suggested using selfie sticks to assist patients with the examination of the back of their body to improve visualization during skin self-examination. Geronazzo et al. [10], in contrast, used selfie sticks in a virtual reality system to capture individual acoustic features to personalize head-related transfer functions. Hasan and Noman [11], on the other hand, used selfie sticks together with motion sensors in a smart-home security system to take automatic snapshots upon the detection of a motion.

Some have also proposed alternatives to common selfie sticks and novel selfie stick interactions. Liou et al. [14] developed a hand gear to enable taking self-portraits with different finger motions and gestures. Several commercial products, such as AirSelfie [1] and Elfie [3], integrate four powerful propellers

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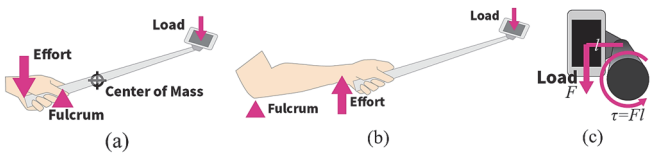

Figure 1. Selfie stick mechanics (a) as a second-class lever, (b) as a third-class lever, and (c) with a portrait orientation grip (i.e., when the smartphone is in a portrait position).

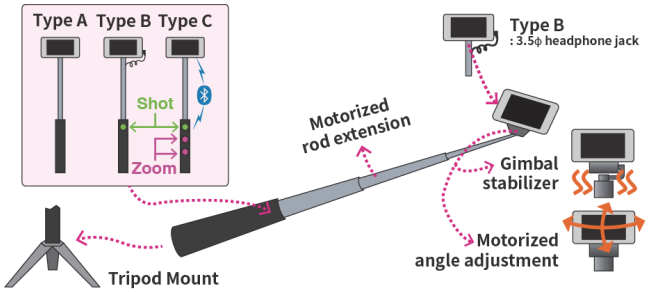

Figure 2. Anatomy of the three common types of selfie stick and the advanced features.

with a video camera to enable taking aerial selfies/videos. In a relevant project, Chen et al. [6] proposed a direct pointing approach to control selfie drones from a user-centric mode.

Although most selfie sticks are designed for smartphones and digital cameras, some have also designed for tablets [2] and laptops, the latter as a joke[1].

TYPES OF SELFIE STICKS

We conducted an informal survey of three widely-used online shopping websites, particularly Alibaba, Amazon, and eBay, to identify the most common types of commercial selfie sticks. We used a simplistic approach for the survey. First, we collected all items listed as "selfie stick" on each website. We, then, divided all items into "inexpensive", "affordable", and "expensive" price ranges, based on the cheapest and the priciest items on the list, to make sure that selfie sticks from different price ranges are covered. Finally, we picked the ten most sold items from each price range for our investigation. Table 1 presents the results of the survey.

SELFIE STICK MECHANICS

Practically, a hand holding a selfie stick could be abstracted as a second-class lever, Figure 1 (a). In this lever, the effort arm is usually shorter than the load arm, hence the effort is almost always greater than the load. This could be a source of fatigue, particularly when the user is adjusting the angle of a selfie stick. This could be addressed by either using a shorter arm or adding an extra mass to the handle, such as the pommel of a sword, to move the center of the mass towards the hand.

If we extend our view to the elbow, the whole system could be abstracted as a third-class lever, Figure 1 (b). In this lever, a longer arm and a heavier mass could induce fatigue on the biceps. As a result, using a heavy handle for better handling, as we suggested earlier, could further increase arm fatigue.

In some scenarios, such as when the smartphone (or camera) is in a portrait position, Figure 1 (c), the load shifts from the center and induces torque ($\tau = Fl$). In such scenarios, selfie sticks with a narrow or a slippery handle would require more forceful grips to control the friction to prevent any unwanted rotations. This could cause fatigue in the hand and the lower-arm muscles. Using a wider handle made/covered with anti-skid materials could resolve this.

In summary, the following ergonomic factors could affect the usability of a selfie stick: the overall *weight* of the selfie stick (including the smartphone or camera), the *center of the mass*, and the *shape* and *material* of the handle. The overall weight affects the upper-arm muscles since they are used to support the complete selfie stick. While the center of the mass, and the shape and material of the handle affect the forearm and

Category	Shutter Control	Advance Camera Control	Body Material	Handle/Grip		Phone Holder		Diameter *cm*	Mirror	Length		Joints	Weight *g*	Max. Load *g*	Available Accessories
				Width cm	Material	Clamp	Lock			Folded *cm*	Extended *cm*				
Type A: Timer	Camera Timer	No	Stainless steel or aluminum alloy	2-5	Foam, plastic, or matte rubber-based anti-skid grip	Adjustable silicon grip	Thumb screw	2-3	No	13-23	50-110	5-7	45-181	500-1000	GoPro accessories and custom camera apps
Type B: Wired	3.5mm headphone audio/auxiliary jack	Rarely		2-5				2-4	Rarely	13-25	50-110		45-136	500-1000	None
Type C: Bluetooth	Bluetooth 3.0 or above	Mostly		3-5				2-4	Rarely	18-50	76-125		130-300	500-1000	Tripod and remote control

Table 1. The most common types of selfie stick based on the data from three shopping websites: Alibaba, Amazon, and eBay. Note that the numerical values are rounded for better presentation.

[1] MacBook Selfie Stick. Retrieved February 26, 2017 from http://macbookselfiestick.com

hand muscles since they are used to adjust the angle of the selfie stick.

SELFIE STICK INTERACTIONS

The survey revealed that there are three common types of selfie sticks available in the market, described below.

Type A: Timer-Based Selfie Sticks

This is one of the earliest type of selfie stick that is simply a stick with a smartphone holder attached (Figure 2). This type of selfie sticks does not provide the support for controlling the smartphone via the stick. Hence, users usually use a third-party camera application or the phone's default camera timer and voice command to take pictures.

Type B: Wired Selfie Sticks

This type of selfie sticks use the 3.5 mm headphone jack for connectivity. Most modern smartphones are equipped with a 4-pin headphone jack that adds an extra pin to the traditional 3-pin jack for microphone and control signal. In most of these smartphones, shorting the ground and the microphone pins activates the camera shutter. Wired selfie sticks utilize this to enable taking pictures using a tactile button in the handle (Figure 2). Although this type of selfie sticks typically do not support interactions beyond the shutter control, (presumably) the fact that they use a low-cost and affordable technology (i.e., do not require "pairing" or a separate power supply) makes them one of the most popular type of selfie sticks in the market.

Type C: Bluetooth Selfie Sticks

This type of selfie sticks establishes an explicit Bluetooth communication channel between the stick and the smartphone (Figure 2). Unlike wired selfie sticks, Bluetooth selfie sticks could virtually enable an unlimited number of commands. Hence, most of these selfie sticks enable advanced features, including zooming, photo or video selector, and front or back camera selector. Some models also include extra controllers to control third-party applications to further extend the selfie stick interactions. However, these type of selfie sticks require a separate power supply and must be paired with the phone before use.

Advanced Features

Apart from the features described above, several selfie sticks provide the support for the following advanced features.

Tripod

Some selfie sticks come with a tripod attachments to enable using the selfie stick as a tripod.

Automation

Some selfie sticks use motorized rod expansion or contract and angle adjustment features to enable remote operations. Some also utilize gimbal stabilizers to compensate for hand tremors during video recordings.

A SURVEY

We conducted an online survey to investigate the usability of commercial selfie sticks. The survey used a semi-structured questionnaire. It used a predetermined set of answers for the demographics, selfie stick usage, and fatigue related inquiries, but enabled participants to include their own responses. It used open-ended questions for all other inquires, including the most liked and disliked aspects of the selfie sticks. Requests to participate in the survey were distributed via various emailing lists, online forums, and social community websites. Selfie stick users then could self-select themselves for the survey.

Participants

Among 113 applicants, 105 that responded that they have used a selfie stick at least once participated in the survey. They were predominantly from the Republic of Korea (96%). Their age ranged from 15 to 42 years (average 24.9 years, SD = 4.4). About 37% ($N = 39$) of them were female and 63% ($N = 66$) were male.

Group	Selfie Stick Category	Percent	*N*
1	*Type A:* Timer	16.2	17
	Type A: Timer, *Type B:* Wired	20	21
4	*Type A:* Timer, *Type B:* Wired, *Type C:* Bluetooth	17.1	18
	Type A: Timer, *Type C:* Bluetooth	8.6	9
2	*Type B:* Wired	21	22
4	*Type B:* Wired, *Type C:* Bluetooth	5.7	6
3	*Type C:* Bluetooth	11.4	12
	Total	100	105

Table 2. Different types of selfie sticks (Table 1) owned by the participants. "*N*" represents the total number of responses.

Selfie Stick Usage

About 63.8% of the participants owned *Type B* selfie sticks, while 61.9% and 42.8% owned *Type A* and *Type C* selfie sticks, respectively. Notice that the values do not add up to a 100% since 42.8% ($N = 54$) of the participants owned more than one selfie sticks. Table 2 displays the different types of selfie sticks owned by the participants.

Majority of the participants (37.7%) owned their selfie sticks for less than six months, while about 27.4%, 19.8%, and 15.1% of them owned their selfie sticks for over six months but less than year, over a year but less than two years, and over two years, correspondingly.

Data revealed that only one participant (male, 24 years) always kept his selfie stick with him. The remining 99% took their selfie sticks with them only when they were planning on using it. Likewise, most of the participants (66.7%) responded that they carried their selfie sticks in hand only when they had the intention of using it in quick succession, such as at a social event (e.g., a wedding ceremony) or when travelling abroad. About 30.5% of the participants responded that they put their selfie sticks away when they were not using it (e.g., kept it in a handbag). The remaining 2.8% never carried their selfie sticks in hand.

Importance

About half of participants (55.2%) did not consider selfie sticks to be an important gadget for their day to day activities, while about 20% found it important. The remaining 24.8% were neutral about it. For statistical analysis, we divided the

participants into four groups: the owners of *Type A*, *B*, and *C* selfie sticks, and the owners of multiple types of selfie sticks (Table 2). A Kruskal-Wallis test identified a significant effect of group on importance ($\chi^2 = 14.856$, $p = .002$, $df = 3$). A Tukey's HSD test revealed that *Type A* selfie stick owners found the devices significantly ($p < .05$) less importance than *Type B* ($p = .046$) and multiple types of selfie stick owners ($p = .001$). However, a Mann-Whitney U test failed to identify a significant effect of gender on importance ($U = 1043$, $p = .092$).

Willingness to Upgrade

Most of the participants (45.7%) did not want to upgrade to a better or smarter selfie stick, while about 33.3% of them wanted to. The remaining 21% were undecided about this. A Kruskal-Wallis test identified a significant effect of importance on willingness to upgrade ($\chi^2 = 13.246$, $p = .001$, $df = 2$). A Tukey's HSD test suggested that users that found selfie sticks important are more likely to upgrade to a better or smarter selfie sticks ($p = 0.001$).

Usage Frequency

Results revealed that none of the participants used their selfie sticks daily. About 2.9% of them used their selfie sticks at least once a week, 9.5% used several times a month, 10.5% used at least once a month, 75.2% used their selfie sticks rarely, e.g., once in two months, and the remaining 1.9% used their selfie sticks very rarely, e.g., several times a year. A Kruskal-Wallis test found a significant effect of usage frequency on importance ($\chi^2 = 12.439$, $p = .014$, $df = 4$). However, Tukey's HSD test did not identify a significant difference between the five frequency groups. A Mann-Whitney U test also failed to identify a significant effect of gender on usage frequency ($U = 1427.5$, $p = .218$).

Most Liked Aspects

Below are the most liked aspects of commercial selfie sticks.

1. Ability to take pictures and videos with wider backgrounds and landscapes (68.6%),
2. Ability to take self-portraits without the assistance of the others (27.6%),
3. Ability to take group pictures with ease (26.7 %), and
4. Ability to enhance the composition and aesthetics (21%).

Most participants appreciated that selfie sticks allow them to take better pictures. Many appreciated that the devices enable taking pictures with a wider background and landscape; and without the assistance of the others. For example, one male participant (21 years) wrote, *"[I like that it allows me to] take wider shots with the landscape and my friends"*. A female participant (24 years) wrote, *"[Selfie sticks allow me to] take selfies even when there's no one around"*. Many also praised the dynamic compositions enabled by selfie sticks, including the low-angle and high-angle shots. For instance, a male participant (24 years) commented, *"[I like that now] I can compose beautiful pictures with dynamic angles [with my selfie stick]"*.

Most Disliked Aspects

Below are the most disliked aspects of selfie sticks.

1. The devices are heavy and bulky (55.2%),
2. The preparation involved with using a selfie stick, such as mounting the phone and expanding the rod (12.4%), and
3. [Tied] The devices are not durable (9.5%), the rod is often conspicuous to others (9.5%), and the fear of accidentally dropping the smartphone or camera (9.5%).

Most participants disliked the portability of selfie sticks. They found selfie sticks to be too heavy and bulky to carry around. For example, one female participant (27 years) wrote, *"[I would prefer] a more compact selfie stick for my phone"*. Some also mentioned other issues associated with the length and weight of the devices. For instance, one female participant (20 years) wrote, *"The length and weight of the selfie stick often makes my hand tremor"*.

There were also some type specific criticisms. For instance, several *Type A* selfie stick users complained about the absence of a shutter button. Similarly, several *Type C* selfie stick users complained about the fast battery-drain.

Desired Improvements

The most liked and disliked aspects align with user responses to the question, *"If you could change one thing about your selfie stick, what would it be?"*. Roughly 36.2%, 12.4%, and 12.4% of the participants responded that they would like to change the *volume* and *weight* (i.e., would make them smaller, thinner, and lighter), the *holder design*, and the *connection* method of the selfie sticks. For example, several *Type A* users wanted shutter buttons, and some *Type B* owners wanted more reliable 3.5 mm jack connection. In addition, 9.5% wanted a more durable and 5.7% wanted longer rods. About 5.7% of the participants wanted better tactile buttons since using hard-to-press buttons tend to shake the device, resulting in blurry images.

The most liked and disliked aspects also correspond to user responses to the question, *"What is the 'one' thing you would consider in your next selfie stick purchase?"*. Participants responded that the price (27.6%), portability (21.9%), durability (21%), solid holder (18.1%), functionality (14.3%), and the convenience (11.4%) of the selfie sticks would influence their choice the most.

Physical Stress

Most of the participants (72.4%) responded that they have experienced physical discomfort or fatigue due to selfie sticks, while about 12.4% reported that they did not experience any discomfort. The remining 15.3% of them were uncertain about this.

The following sections present further analysis on the 72.4% participants that reported physical discomfort or fatigue due to selfie sticks.

Most participants (98.8%) reported short-term fatigues that appeared only when using the device and disappeared with

Frequency	Gender	Finger	Hand	Forearm	Upper Arm	Shoulder	Neck	Other	None	*N*
Once a week	Female	33.3 (1)	0 (0)	33.3 (1)	0 (0)	0 (0)	0 (0)	33.3 (1)	0 (0)	1
	Male	50 (2)	25 (1)	25 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2
	Total	**42.8 (3)**	**14.3 (1)**	**28.6 (2)**	**0 (0)**	**0 (0)**	**0 (0)**	**14.3 (1)**	**0 (0)**	**3**
Several times a month	Female	11.1 (1)	22.2 (2)	33.3 (3)	11.1 (1)	11.1 (1)	0 (0)	11.1 (1)	0 (0)	4
	Male	27.3 (3)	36.4 (4)	9.1 (1)	0 (0)	18.1 (2)	0 (0)	0 (0)	9.1 (1)	6
	Total	**20 (4)**	**30 (6)**	**20 (4)**	**5 (1)**	**15 (3)**	**0 (0)**	**5 (1)**	**5 (1)**	**10**
Once a month	Female	0 (0)	0 (0)	100 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
	Male	15 (3)	15 (3)	20 (4)	10 (2)	5 (1)	10 (2)	15 (3)	10 (2)	10
	Total	**14.3 (3)**	**14.3 (3)**	**23.8 (5)**	**9.5 (2)**	**4.8 (1)**	**9.5 (2)**	**14.3 (3)**	**9.5 (2)**	**11**
Rarely: Once in two months	Female	17.3 (13)	22.7 (17)	20 (15)	13.3 (10)	16 (12)	1.3 (1)	2.7 (2)	6.7 (5)	32
	Male	13.3 (11)	24.1 (20)	25.3 (21)	7.2 (6)	9.6 (8)	2.4 (2)	4.8 (4)	13.3 (11)	47
	Total	**15.2 (24)**	**23.4 (37)**	**22.8 (36)**	**10.1 (16)**	**12.7 (20)**	**1.9 (3)**	**3.8 (6)**	**10.1 (16)**	**79**
Almost never: Several times a year	Female	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
	Male	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
	Total	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**2**

Table 3. Self-reported fatigue due to selfie sticks, normalized within the usage frequency. The values inside the parenthesis are the raw number of responses. Here, "Other" and "*N*" signify other body parts (e.g., the wrist) and the total number of responses, respectively.

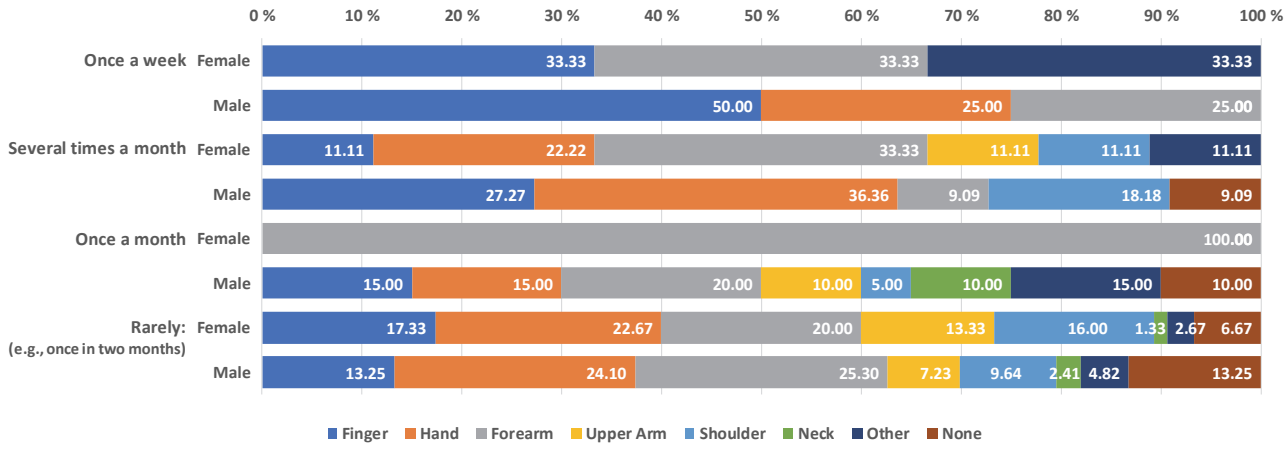

Figure 3. Self-reported fatigue due to selfie sticks, normalized within the usage frequency.

rest. Only one participant (1.2%) reported long-term (or chronic) fatigues that did not go away with rest and appeared even when not using the device. Table 3 displays self-reported physical stress due to selfie sticks.

Based on user responses, the most fatigued body parts were forearm (45%), followed by hand (44%), and fingers (33%). Shoulder (23%) and upper arm (19%) were moderately fatigued, followed by wrist (9%) and neck (3%). Interestingly, about 2.8% of the participants also reported mental stress due to the anxiety of dropping their smartphone or camera.

Since the survey did not measure explicit fatigue levels, we counted the number of fatigued body parts for each user and used it as their *fatigue score* for further analysis. For example, if a user reported fatigue in three body parts, his/her fatigue score was three.

A Kruskal-Wallis test failed to identify a significant effect of usage frequency on fatigue score ($\chi^2 = 3.228$, $p = .520$, $df = 4$). For further analysis, we filtered the data for the users that did not experience any physical discomfort due to selfie stick. A Kruskal-Wallis test on the data failed to identify a significant effect of usage frequency on absence of fatigue ($\chi^2 = 2.535$, $p = .638$, $df = 4$).

The average fatigue score for female and male were 2.08 (SD = 1.4) and 1.47 (SD = 1.06), respectively. However, a Mann-Whitney U test *marginally* failed to identify a significant effect of gender on fatigue score ($U = 1003$, $p = .052$). For further analysis, we filtered the data for the users that used selfie sticks rarely (Table 3) since they represent the majority of the participants (75%). Nevertheless, a Mann-Whitney U test *marginally* failed to identify a significant effect of gender on fatigue score ($U = 566.5$, $p = .057$).

DISCUSSION

Results revealed that most participants (76%) were occasional users of selfie sticks, suggesting that selfie sticks are still not

an everyday device. Most users used selfie sticks at special occasions, such as when travelling or attending a social event.

There was a significant effect of selfie stick type on perceived importance of selfie sticks. Evidently, *Type A* selfie stick users found selfie sticks less important than the other users. This suggests that users that find selfie sticks unimportant tend to settle for cheaper, *Type A* selfie sticks. Expectedly, there was a significant effect of importance on willingness to upgrade, suggesting that users that find selfie sticks important are likely to upgrade to better or smarter selfie sticks.

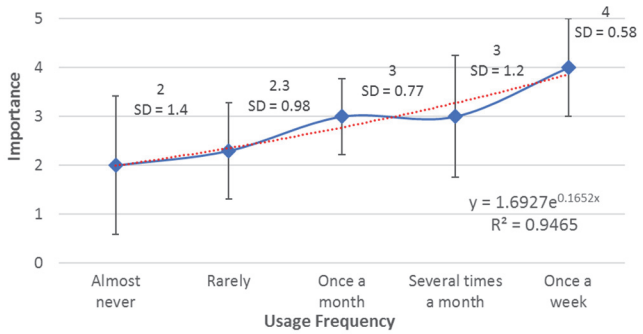

Figure 4. Relationship between selfie stick usage frequency and perceived importance of selfie sticks. Error bars represent ±1 standard deviation (SD).

There was a significant effect of usage frequency on importance, but a post hoc analysis failed to identify a significant different between the different frequency groups. However, in Figure 4 one can see that the data correlates well with an exponential function ($R^2 = 0.95$), suggesting a *weak* relationship between usage frequency and importance (i.e., perceived importance of the devices increase with usage frequency). Similarly, there was no significant effect of gender on importance, although on average female participants considered selfie sticks more important than male participants, Figure 5.

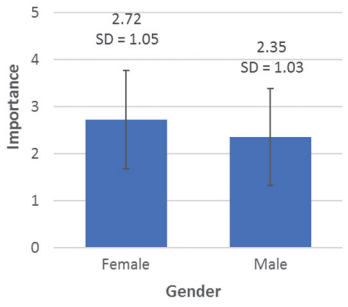

Figure 5. Importance of selfie sticks by gender. Error bars represent ±1 standard deviation (SD).

Other than the ability to take self-portraits, many participants praised the ability to capture a wider background. The typical angle of view for smartphone cameras is around 60°, which is comparable to the ~35 mm focal length of the 35 mm films. Hence, when taking a self-portrait using the arm (~1 m) in the 4:3 aspect ratio, the human bust (~60 cm vertically) covers almost 50% of the frame area. Most selfie sticks free up the space by 25% by extending the view, allowing users to capture a wider background or take group pictures. Interestingly, some users responded that they use a selfie stick because it enables adjusting the angle of view. For example, one male participant (21 years) wrote, *"I can take wide-angle shots with selfie sticks"*. But, in practice, focal length is the only factor that determines the angle of view since most smartphone cameras use lenses with a fixed focal length. Users get a wider view with a selfie stick due to the extended distance between the user and the camera, which is fundamentally different from zooming out using lenses with a variable focal length.

Most participants complained about the portability of the selfie sticks. Apparently, they found the volume and weight of the devices inconvenient, even when folded. They also reported that operating selfie sticks is often tiresome, especially when obstructed by the crowd or other obstacles.

Results suggest that using selfie sticks cause short-term fatigue in all major arm and shoulder muscles. Evidently, most selfie sticks are designed to amplify the weight of the phone or camera, which is an obvious cause of fatigue when holding a selfie stick. Although, there was not sufficient data to fully investigate the potential of chronic fatigues, the extent of the short-term fatigues (Table 3) suggests that they could turn into chronic over the time and with extensive use.

Interestingly, there was no significant effect of usage frequency on fatigue score and the absence of fatigue. Results revealed that on average female participants reported 29% higher fatigue than male participants. Yet, there was no significant (but a marginal) effect of gender on fatigue score ($p = .052$), even for the users that used selfie sticks rarely ($p = .057$), see Table 3, the dominant group in the survey. However, we recommend caution in interpreting these results since the survey data was insufficient to thoroughly explore the effects of usage frequency and gender on fatigue (e.g., the "Once a week" group involved only three participants, Table 3).

Recommendations

To reduce fatigue in the major arm and shoulder muscles due to the second-class lever, Figure 1 (a), we recommend using a shorter arm or adding counterweight to the handle, such as the pommel of a sword. However, this is a trade-off since adding counterweight could increase fatigue due to the third-class lever, Figure 1 (b). Using a lightweight material for the rod, such as carbon fiber composite, could resolve this.

Since selfie sticks with a narrow or slippery handle frequently require forceful grips to control the friction to prevent any unwanted rotations, we recommend using a wider handle, either made or covered with anti-skid materials, to reduce fatigue in the finger, hand, and lower-arm muscles.

Finally, we suggest automating repetitive features that could cause repetitive strain injuries (RSI), such as angle adjustment. However, this solution requires additional hardware and sensors that could increase the price of the devices. Since the affordability of the selfie sticks is one of the most desired factors (25%), it is important to maintain a balance between the functionality and the cost of these devices.

LIMITATIONS AND FUTURE WORK

There are several limitations of the work. First, as the survey required participants to self-reported fatigues associated with selfie sticks, it is possible that some fatigues were caused by a different action and/or by a pre-existing condition. Second, about 96% of our participants were from the Republic of Korea, introducing a potential cultural bias. Third, the survey failed to gather sufficient data to fully explore the effects of usage frequency and gender on fatigue. We will address these in a future user study by increasing our sample size (*N*) and broadening our participant pool.

We also failed to investigate the long-term effects of selfie sticks since most participants were either new or infrequent users of the devices. However, considering that selfie stick is a relatively new gadget, it might be too early to explore its long-term effect. Therefore, we included an optional field in the survey that asked the volunteers to enter their emails for a follow-up study. About 95% of them responded to this request. Our plan is to revisit the survey in a few years to find out if the users continued using their selfie sticks, upgraded or downgraded to different selfie sticks, and the long-term effects of the selfie sticks.

Finally, we intend to extend our research to other low-cost smartphone accessories targeted at the millennials, such as smartphone cases, stands, holders, and power banks.

CONCLUSION

In this paper, we reviewed and categorized the most common types of selfie sticks available in the market, and discussed their design and usability. Through a theoretical analysis, we demonstrated how most commercial selfie sticks ignore vital human factors, i.e., ergonomics. We then presented results of an online survey, where 105 selfie stick users, predominantly from the Republic of Korea, rated the usability of their selfie sticks. Survey results also suggested that most commercial selfie sticks are unergonomic, causing the users short-term fatigues that could "in theory" turn into chronic over the time with extensive use. Results also provided an insight into users' selfie stick usage behavior, their most liked and disliked aspects of selfie sticks, and their take on how to improve the usability of the existing selfie sticks. Finally, based on the findings of the survey, we made recommendations for future development.

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