Does motivation play a role in Dunbar's number? A new perspective on the limitations of social network sizes

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Abstract

The social brain hypothesis predicts that (typically developed) adult humans have a natural social network size of around 150 'friends' (active social network), known as Dunbar's number. It is predicted that humans cannot maintain more than ~150 relationships at any one time due to constraints of cognitive processing and time. These limitations affect the quality of relationships and thus, ultimately, the total number that one can maintain. The current paper explores whether *motivation* may be another factor to this equation: how motivated are people to get in touch with their friends? A pilot study was performed, whereby 21 participants used a mobile app on their smartphone to fill out multiple surveys per day over the course of 7 days. Participants were asked to estimate their motivation to contact friends, provided their social network sizes, and were evaluated on their ability to handle multi-level intentionality tasks (a.k.a. theory of mind/mentalising). An investigation into correlations between individual motivation, social network sizes, and theory of mind capabilities is presented. Results are inconclusive, potentially due to a small sample size and too much noise in the social network size data.

*Keywords: m*otivation, social network sizes, theory of mind, Dunbar's number

I. Introduction

Humans are the only species that have been able to evolve to live in large cities and whom constantly manage their lives with vast amounts of information (Gamble, Gowlett, & Dunbar, 2014, pp. 13). Yet, humans haven't always lived in large societies, so how did this come to be? How did humans work together to build the cities we now live in and how do we live with each other? One common conclusion is that we are social beings who live in complex societies. These are determinate of how individuals interact with each other and subsequently the sizes of their social groups (Gamble et al., 2014, pp. 17). In the 1990's, it was observed that the average size of species' social groups correlated with the size of its brain (Gamble et al., 2014, pp. 17-18). According to Gamble et al. (2014, pp. 18) the neocortex has increased in size during the course of primate evolution and is the main reason primates have larger brains than other mammals. These observations support the Social Brain Hypothesis which states that group size is an effect of how well animals handle complex relationships (Dunbar, 2009) and this social complexity drives the evolution of brain size (Dunbar, 2007). When accounting for humans in this equation, the hypothesis predicts a natural group size around 150, which is known as Dunbar's number (Dunbar, 2012). It is also important to note that not everyone agrees with this, as Adolphs (1999) has pointed out that it has also been proposed that brain size is the consequence of other factors such as dietary foraging strategy, tool use, and longevity. Yet, current studies suggest an increasing amount of supporting evidence which validates Dunbar's number (see, for example, Hill, R.A. & Dunbar, R.I.M., 2003; Dunbar, Arnaboldi, Conti, & Passarella, 2015; Zhou, Sornette, Hill, & Dunbar, 2005; Powell, Lewis, Roberts, Garcia-Finana, & Dunbar 2012). Furthermore, studies have been performed to investigate social group sizes from other perspectives such as the use of mobile phones (see MacCarron, Kaski, & Dunbar, 2016), Social Networking Sites (SNS) and IM (see Pollet, Roberts, & Dunbar, 2011), Theory of Mind capabilities (see Powell, Lewis, Dunbar, García-Fiñana, & Roberts, 2010), and individual olfactory function (see Zou, et al., 2016). And yet, thus far, there have been no known studies that investigate the role individual motivation

plays in individual social network sizes. Does motivation play a role in Dunbar's number? What is motivation, and is there a relationship to social network sizes? Furthermore, how can motivation be operationalized in a study? In this paper I will explain Dunbar's number and its layers, as well as the known suggested constraints of this number; time and cognition. Further, I will provide a concise explanation of motivation and suggest motivation as a possible third constraint of Dunbar's number. After, I will discuss the pilot study that was performed to investigate individual motivation in relation to individual social group sizes, along with the results.

II. Dunbar's Number

The Social Brain Hypothesis is an explanation for the evolution of the brain size in primates and states that the average size of a primate's' social group is correlated with the size of its neocortex (the outer layer of the brain responsible for complex thought) (Gamble et al., 2014, pp. 18-19). This hypothesis predicts that the natural social group size for humans is around 150, known as Dunbar's number (Dunbar, 2012). Not only does Dunbar's number have an upper limit of 150, but Roberts, Dunbar, Pollet, and Kuppens (2009) discovered and identified a structural pattern of layers within Dunbar's number. These hierarchical inclusive layers have a natural scaling ratio of approximately 3 (Dunbar, 2016). The first layer consists of approximately 5 people, which has been labelled as the support group (Sutcliffe, Dunbar, Binder, & Arrow, 2012). The second layer contains 15 people, including the support group, and has been labelled as the sympathy group (Sutcliffe et al., 2012). When we continue onwards with the ratio of 3 we come to the next two groups, the affinity group containing 50 people, and lastly the active network, containing 150 people (Sutcliffe et al., 2012; see Fig. 1). According to Gamble et al., (2014, pp. 21) these layers are approximately equivalent to an individual's intimate friends, best friends, good friends, and friends. Additionally, about half of the individuals that fall within our individual networks are extended family members (Gamble et al., 2014, pp. 23). Beyond the active network layer Dunbar (2016) suggests that there are two other layers which contain acquaintances (people we would not consider as personal friends or family, but know well

enough to have a conversation with) and the number of faces we can put names to, with values of 500 and 1500 respectively (Dunbar, 2016).

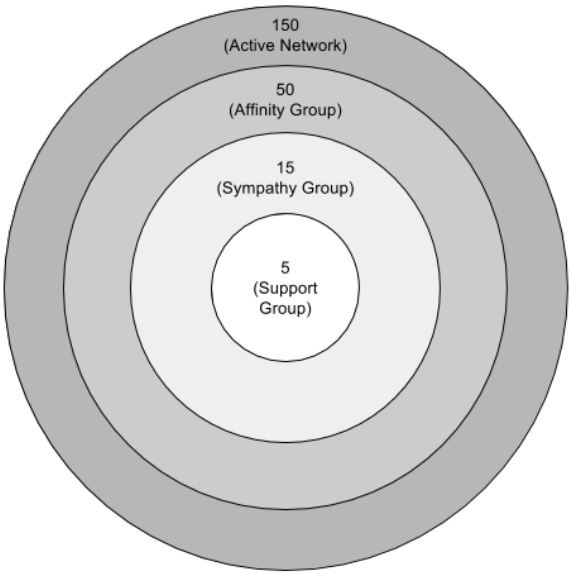

Figure 1. Dunbar Layers. This figure illustrates the layers within Dunbar's number.

Evidence suggests that the limitations of Dunbar's number has something to do with constraints of time and cognition (Dunbar, 2012). Time is needed to invest into a relationship and maintain it at a necessary level of emotional intensity and the cognitive constraint is due to the size of our brains (Dunbar, 2016).

A. Constraints of Dunbar's number

1. Cognition. According to Gamble et al. (2014, pp. 50) the psychology of human relationships is contingent on the ability to mentalise, or rather the ability to understand another's intentions and mind state. This ability refers to understanding what someone else is trying to convey through language, audio cues, or gestures, and humans use this skill on a daily basis to figure out what others want, how they might react to what we do, and how best to act in order to get others to do what we want them to (Gamble et al., 2014, pp. 51). And as stated by Adolphs (1999), the cognitive process that drives diverse and flexible social behaviors seen in primates is labelled as social cognition. And although psychologists, philosophers, anthropologist, ethologists, and neuroscientists have all contributed research into social cognition, still most attention is focused on the skill of mentalising,

also known as Theory of Mind (ToM) (Duijn, 2016). It is important to note that social cognition is quite important because it is required to live in groups structured by social bonds and networks (Duijn, 2016), which has, in part, made cognitive achievements such as language possible (to be discussed in section III).

Theorists have argued that the cognitive process is the result of neuron activity in the brain, and others have contended that cognition is mostly distributed over the entire body, or over the environment (Duijn, 2016). According to Dunbar's TEDx presentation (2012), social cognition in humans consists of the neocortex, which is responsible for managing social interactions, and temporal lobes - all of which determines the number of friends an individual has. Neuroimaging studies have supported this by showing that humans with larger brain regions in the prefrontal cortex have more active social contacts (Dunbar, 2012). Evidence also suggests that there is a relationship between individual social network size and cognitive abilities, which was indexed by the ability to handle multi-level intentionality tasks (Dunbar, 2012). And although the cognitive processes involved are not yet fully understood, there is increasing evidence suggesting that executive functions play an important role (Dunbar, 2012; Powell et al., 2010). Cognitive processing is quite demanding, according to Dunbar (2009), in which the neuron activities of allocation and the processing of tasks take place.

Additionally, Gamble et al. (2014, pp. 24) take the stance that our cognitive ability to remember, recall and react in consistent and socially productive ways is limited, and thus limits the amount of social relationships that can be effectively maintained. Observations of primates' social groups who exceed their limit (the social group size determined by the size of the brain) have revealed that relationships begin to fall apart as they are not able to manage and maintain coherent relationships with each other (Gamble et al., 2014, pp 18). Gamble et al. (2014, pp. 18) has stated two important aspects of this, one being the psychological component that is the ability of primates to strategize and deceive, and the other is that social cognition is very expensive in computational terms as the neurons in the brain have to work quite hard.

2. Time. Time is another constraint on Dunbar's number. The amount of time an individual has available to invest into a relationship affects the quality of the relationship, and possibly the size of the social network (Dunbar, 2012). According to Dunbar, relationships depend on a cognitive mechanism that creates relationships of trust and obligation, and an emotional component that creates the underpinnings for this (Dunbar, 2012).

An investment of time is required to build trust and an emotional closeness, and this investment determines a level to which they are developed, and ultimately the quality of the relationship (Dunbar, 2012). Interacting with another in this way is termed as social bonding (Dunbar, 2012). According to Gamble et al. (2014, pp. 55), social bonding in primates seems to involve a dual-process mechanism: one part involving our cognitive abilities that makes it possible to do mental calculations like mentalising, and the other part is a chemical production of endorphins. The release of endorphins also gives the same uplifting feeling produced by morphine and other opiates (Gamble et al., 2014, pp. 56). Gamble et al. (2014, pp. 56), further explain that not only do endorphins make you feel good and wanting to come back for more, but they also create a relaxing effect that gives a psychological frame of mind that allows humans to build a relationship of trust with the individual they are interacting with.

Monkeys and apes use fingertip grooming as a mechanism to socially groom each other, which results in an endorphin release, and effectively allows for social bonding to occur (Gamble et al., 2014, pp. 56). Dunbar (Gamble et al., 2014, pp. 143) has suggested that humans used to socially groom each other in a similar manner, but fingertip grooming evolved as human brain sizes increased and social groups became larger. Dunbar (Gamble et al., 2014, pp. 143) further explains that social grooming (by means of fingertip grooming) shifted to other mechanisms due to demands of maintaining larger amounts of social relationships and with no change in the time available to socially bond. He suggests solutions as being the use of fire to extend the length of the social day, vocal grooming which lead to spoken language, gestures and exclamations, and laughter (Gamble et al., 2014, pp. 143). The use of

these mechanisms for social grooming became efficient ways to use the time available to socially bond with others and increase social group sizes.

Additionally, the time an individual invests in social bonding with another creates, and builds upon, levels of perceived emotional closeness (Dunbar, 2012). Dunbar (2016) states that emotional closeness is a consequence of a few factors: the amount of time one has to socialise with another, the time invested into each relationship, and its quality (as rated in terms of emotional closeness). Dunbar (2012) argues that as the frequency of interaction in friendships declines, the perceived emotional closeness deteriorates. As such, the layers act as direct reflection of the frequency of interactions and emotional closeness (Dunbar, 2016) one has with members of their social network. According to MacCarron et al., (2016), the perceived emotional closeness decreases for members of the social group that fall into the outer layers in comparison to group members in the innermost layers. Roberts et al., (2009), explain that individuals that fall into the two inner layers, support and sympathy, of the active social network provide extensive emotional, instrumental and social support, which takes a long history of interaction and emotional commitment to build and maintain these relationships. Furthermore, it is stated that weak emotional ties exist in the more distant acquaintances, and are less important in providing emotional support (Roberts et al., 2009). To conclude, all social bonding activities require time, which effects social network sizes.

III. The Case for Motivation

There are quite a few theories on motivation, but generally motivation refers to internal or external factors that compel one to act (Locke & Latham, 2004), but more importantly, for purposes of this study, it is correlated with cognition and shared intentionally (Burkart, Hrdy, & Van Schaik, 2009). In order to address this aspect, I must first provide a brief evolutionary background that explains why motivation could play a role in sociality and, consequently, social group sizes.

Around 6 to 7 million years ago the hominin lineage split from the rest of the great ape, and although humans share many biological traits and behavioral and cognitive similarities, humans have extraordinary differences (Burkart et al., 2009). One such difference, that makes us uniquely human, is

shared intentionality (Burkart et al., 2009). Shared intentionality, a term used that groups together a series of social-cognitive and social-motivational skills, is when an individual shares their psychological state with another during a collaborative interaction (Tomasello & Carpenter, 2007). During these interactions the individuals are able to learn through others and their artifacts and collaborate with others as a collective (Tomasello & Carpenter, 2007). Burkart states that shared intentionality is based on a cognitive component, the understanding of others' goals and intentions, as well as on a motivational component, the desire to do something (Burkart et al., 2009). Furthermore, shared intentionality is important because it is based on a prosocial motivational predisposition that involves an interest in sharing psychological states with others (Burkart et al., 2009). This is a uniquely human trait because humans, as opposed to chimpanzees for example, attempt to share attention with others (Bakeman & Adamson, 1984) and understand that the joint attention they are experiencing is being done together (Tomasello, 1995). Tomasello and Carpenter (2007) state, "...it is clear that from a very early age human infants are motivated to share interest and attention with others in a way that our nearest primate relatives are not" (p. 122). Tomasello and Carpenter (2007) further explain that shared intentionality is important in transforming the basic understanding of other minds into joint attention, cooperative communication, collaboration, and instructed learning, which produce further cognitive developments (Burkart et al., 2009). According to Burkart, shared intentionality has been identified as the fundamental source for the majority of our unique cognitive achievements, which include language, complex technologies, art, and formalized norms and institutions, which also gave rise to religion (Burkart et al., 2009). In order to achieve these feats, humans had to be social and rely on their social relationships and interest in sharing, cooperating, and collaborating with each other (Burkart et al., 2009). Consequently, our cognitive achievements have helped form large complex societies (Burkart et al., 2009).

If shared intentionality is the underpinning to being social, and thus forming social relationships, it would be crucial to investigate the two known components of shared intentionality; motivation and cognition, in order to determine if either component plays a role in the limitations of social network

sizes. Thus far, much research has focused on the cognitive component and its relationship to social network sizes, yet there are no known studies that research motivation in relation to social network sizes. Acedi-Carmona and Gomila (2016) address this in their paper titled *A critical review of Dunbar's social brain hypothesis*, by stating "a more solid ground in the search for social universals can be found in the basic need for affiliation and our prosocial motivations" (p. 7). We agree, and hypothesize that individual motivation plays a role in individual social network sizes, thus individuals with higher motivation would have larger social network sizes, and possibly better Theory of Mind capabilities.

To investigate our hypothesis, our study seeks to answer the following research questions: (a) Does motivation play a role in Dunbar's number? (b) What is motivation, and is there a relationship to social network sizes? and (c) How can motivation be operationalized in a study? The pilot study performed uses surveys to operationalize motivation as how motivated participants were to interact with their friends. Participants also provided a portion of their social network sizes and completed a mentalising test in order to examine any correlations between individual motivation, social network sizes, and Theory of Mind capabilities.

IV. METHOD

A. Participants

The pilot study started with 29 participants, of which 23 participants completed the study. A completed study was defined as any participant that filled out at least 50% of the 21 motivation surveys and finished the exit survey containing the social network size and Theory of Mind tasks. Participants filled out a total of 430 motivation surveys (range = 13 to 21; M = 18.7, SD = 2.4). Data from two participants were excluded from analysis due to submitting clearly inaccurate data. This left us with a sample of 21 participants (10 females, 11 males; ages 24 to 61; M_{age} = 35.4, SD_{age} = 12.8), of which 12 used the Android mobile app SurveyApp and 9 used the mobile app WhatsApp (see section C below).

B. Design and Procedures

To research motivation, participants are asked via online surveys to estimate their motivation to contact specific members of their social network on a daily basis over the course of a week. Participants are initially asked to "list at least 15 friends for whom they have contact details and with whom they consider to have some kind of personal relationship (friend; acquaintance; someone you might interact with on a regular basis at school, work, or university)", which is a version of a question used by Roberts and Dunbar (2015) in a previous study to identify friends. In the version by Roberts and Dunbar, they ask the participant to list all friends, and here participants are only asked to name 15 friends in an aim to acquire members within the inner two layers of the social network (support and sympathy group). These groups have on average 15 members and it has previously been reported that these members are positively correlated with the frequency of interaction and intimacy between Ego and Alter (Sutcliffe et al., 2012). Additionally, it has also been reported that close friendships show more interactions during the week, across a wider range of days and times than casual friendships (Hays 1989; Sutcliffe et al., 2012). For a week long study, it is then appropriate to only identify members within the inner two layers for whom the participant has frequent interaction with. The names provided by the participants are then stored as URL variables and used in subsequent online surveys, whereby the participant is asked to estimate their motivation to contact these individuals. Contact is defined for participants as some form of interaction, including face-to-face, phone call, email or text-messaging, or a letter. Motivation is self-reported by participants on a 100-point sliding scale ranging from 0 (*not motivated)* to 100 (*very motivated)* for each name they provided. Past work has investigated the accumulation of intrinsic and extrinsic task-specific sources of motivation over the course of a workday, and evidence suggest that they may exhibit within-day fluctuations (Benedetti, Diefendorff, Gabriel, & Chandler, 2015/6). As we want an average motivation value for each friend, participants are asked to estimate their motivation 3 times per day (morning, afternoon, and evening) over the course of 7 days.

Included in the motivation surveys, participants were asked at the beginning of each day to identify any people from their list of 15 friends with whom they had plans to contact that day. At the end of each day they are asked to identify who they had contact with from their 15 friends. These questions are asked to see if there are any relationships between motivation scores, planned interactions, and actual interactions.

In order to investigate if motivation has any correlation to individual social network sizes, participants are asked to identify members of their active social network by using a version by Lewis, Rezaie, Brown, Roberts, & Dunbar (2011) that is an adapted version of the full social network size questionnaire used in previous studies (Dunbar & Spoors, 1995; Stiller & Dunbar, 2007; Powell et al., 2010). Lewis et al., (2011) has identified that the adapted version minimized the time and effort required to complete the questionnaire. This survey asked participants to list the initials of everyone whom they had social contact with during the last 7 days and all others in the last 30 days, as well as their gender. Social contact was defined to participants as some form of interaction, including face-to-face, phone call, email or text-messaging, or a letter. Additional instructions asked participants to not include people whom they had contacted for professional reasons (e.g. doctor, lawyer, hairdresser, priest, employer or supervisor, plumber or DIY consultant etc.) unless they considered the interaction to have been mainly social in nature at the time.

An adapted social network size task was distributed to participants four weeks after the end of the initial study. This task asked participants to list everyone they had social contact with in the past 7 and 30 days, but with more instructions to control for one-on-one interactions only. Social contact was defined as some form of one-on-one interaction (including interactions that are face-to-face, phone calls, emails, text messages, one-on-one IM chats, or letters). The additional instructions asked participants to exclude group chats and stressed the importance of spending the time to find the information to provide accurate data. To help participants with this task, it was stated that the use of their phone, calendars (digital/paper), agendas, and photos could be used to help them with the task. It was also stated that participants could scroll through their phone's call history, text messages, IM chats

(i.e. WhatsApp and/or FB messenger), emails, photos, and address book to get this information. In addition to the social network size tasks, participants were asked to identify if they had a romantic partner and their name, as well as list the names of family members with whom they have frequent social contact with. These additional questions were asked to see if motivation averages were higher for romantic partners and family members compared to others listed in the original list of 15 friends.

As theory of mind capabilities have also previously been linked to social network sizes, participants are additionally asked to complete three multi-level intentionality tasks with a version of a test that has been used in past studies (Kinderman, Dunbar, & Bentall, 1998). The task included 3 short stories, with 20 questions pertaining to character intentionality after each story. This task was adapted to allow users to select "True", "False", or "I don't know" to the questions, as opposed to the original which does not include the "I don't know" option. Participants were instructed to answer True or False to each of the questions that follow each story and to try their absolute best to come up with an answer. If they didn't know the answer to a question to the extent that they would have to make a 100% guess, then (and only then) they should choose the 'I don't know' option. Additionally, they were instructed not to guess. With this information we can see if any correlations exist between theory of mind capabilities and motivation. Both the theory of mind task and the social network size task were distributed to participants after they had received 7 days of motivation surveys, as to not influence the motivation research.

C. Materials

1. Smartphones. Many decisions had to be made in order to effectively and efficiently obtain all the required data. Information must be obtained by asking participants for information multiple times a day over a 7-day period. A diary study was considered, whereby participants would be asked to keep a diary, but it is difficult to control when participants would complete the diary and the questions on motivation are specific to the time of day. In a diary study, it is possible the participant is reflecting on how they felt in the past, but the aim of this study to target a participant in their natural environment at exact moments in time. The use of a smartphone was considered to distribute and

collect data from participants as many individuals own a smartphone and carry it with them at all times. According to Sandstrom et al., (2016), more than 2.5 billion people around the world carry smartphones as they go about their daily lives. Using a smartphone to collect social science data is not commonly used, but could prove beneficial for the objectives of this study. Smartphones could also be used in conjunction with an app to collect and store information, which would be accessible to participants any time they had their phone with them. The phone itself also has the capability to notify participants when to provide data via notifications and alarms.

To use the mobile phone to notify participants when to record data and as a device to collect and store the data there are three approaches: build an all-inclusive mobile app, use the phone to connect to a website through the internet, or build a hybrid app that does a little of both. Due to technical limitations and time, it was decided to build a hybrid app for Android devices as a tool to collect data for our pilot study. The mobile app would function as a method of alerting participants when and where to record data and an online website would be used to store the recorded data. As most of the data that will be collected from participants is already set up as paper surveys that could easily be transformed to online surveys, it was decided to implement the motivational questions in the form of a survey as well. In the hybrid app approach participants would need to access online surveys at various times.

2. Online survey application: survey gizmo. There are many existing survey applications available for use, and research was done to decide which one worked best for the method decided upon. One important element the motivational surveys needed was to be built in such a way that each participant's questions were customized with the list of 15 friends they would initially provide. The surveys would also need to have sliding scale questions in order to measure on 100-point scale. Additionally, if participants would be accessing the online surveys from their mobile phones, the surveys would need to be designed to be mobile friendly. Amongst the few applications that met these requirements, Survey Gizmo was found to be the most useful for this study. With Survey Gizmo, it was also possible to automate the design a bit, by offering a way to customize surveys through URL

variables. In this manner a survey could be built with passing variables and used by all participants multiple times, whereby each participant would have customized information in each survey. This would prevent building individual surveys manually for each participant for each day and time. Essentially, if questions needed to be asked 4 times a day, each set of questions (or question) could be set up as individual surveys. The URL variable method would work if participants are asked for the data in the mobile app, and that data was then programmed into dynamic URLs for each participant. Because the mobile app is on individual devices, it was possible to apply this approach.

3. Online surveys. For this study, a total of 8 surveys were created using Survey Gizmo. The first survey, titled Invitation to Participate, was built to invite participants to participate in this study and determine if they use an Android or Apple device. If participants did not use an Android device, they could not download the mobile app. The opportunity was also used to collect their mobile number and if they used WhatsApp, in order to determine if manual notifications could be sent in a scenario where the Android app crashed or did not work correctly. I also realised that I could use this method of distributing surveys for non-Android mobile users, which I will mention later (see section C.5.). If participants used the app, and something went wrong I would also need the URL variables to manually send them alerts, but they would only be stored on the mobile device. To work around this, another survey opens in the web browser after participants submit 15 names within the mobile app. This survey, titled *SurveyApp: Data*, passes the inputted data as URL variables into the survey and confirms to the participant what they see is what they entered within the app and asks them to confirm they are human.

Four surveys were created to investigate motivation, with the following titles: *SurveyApp: Morning, SurveyApp: Afternoon, SurveyApp: Evening, SurveyApp: Day Log*. Each was repeatedly used for the duration of 7 days. The morning survey asks participants two questions: (a) Today, do you have plans to contact any of your friends listed below? Please select the friends whom you plan to contact and (b) At this moment, how motivated are you to contact a friend? Please select your motivation to contact each person listed below. The second question is asked again in the afternoon

and evening surveys (See Fig. 2). The Day Log survey asks participants "Today, did you contact any friends listed below? Please select the friends whom had contact with." In all questions additional text defines contact to participants as some form of interaction, including face-to-face, phone call, email or text-messaging, or a letter. Also, the list of their 15 friends are pre populated into all the question's answers. One survey was created to collect the names of 15 friends for participants without Android devices, titled *SurveyApp: Start Data* and the final survey created was titled *SurveyApp: Exit Survey*. The Exit Survey is sent to the participant after they had completed 7 days of filling out the motivational surveys. The Exit Survey combined the theory of mind task, social network size task, and a study feedback question.

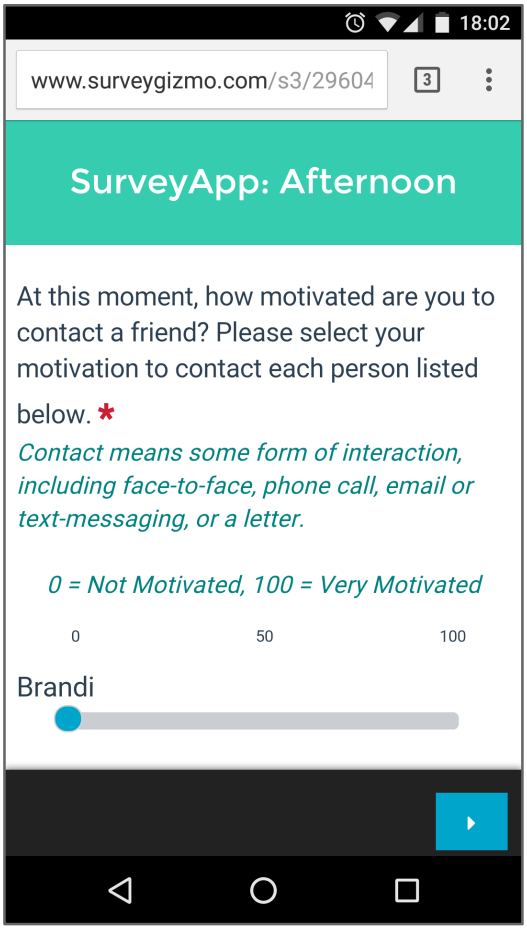

Fig. 2 Screenshot of Survey Gizmo - Afternoon Survey

4. Mobile app: SurveyApp for Android. With the use of Survey Gizmo to provide online surveys, the hybrid mobile app, named SurveyApp, has two essential functions. One is to collect user data to store as URL variables and create dynamic URLs for each participant, and the second is to alert

the user when to fill out the surveys. Each survey needs to be customized with pre populated data, that is sourced from the answers of the initial question whereby participants must list the names of 15 friends. To do this, users are asked to answer this question within the mobile app. Two User Interface (UI) screens were created, one with details about how the study will work for the participant followed by asking them to name 15 friends and the other as a thank you screen which supplied details to notify them that the information had been submitted and instructions on how the study would proceed further (See Fig.3).

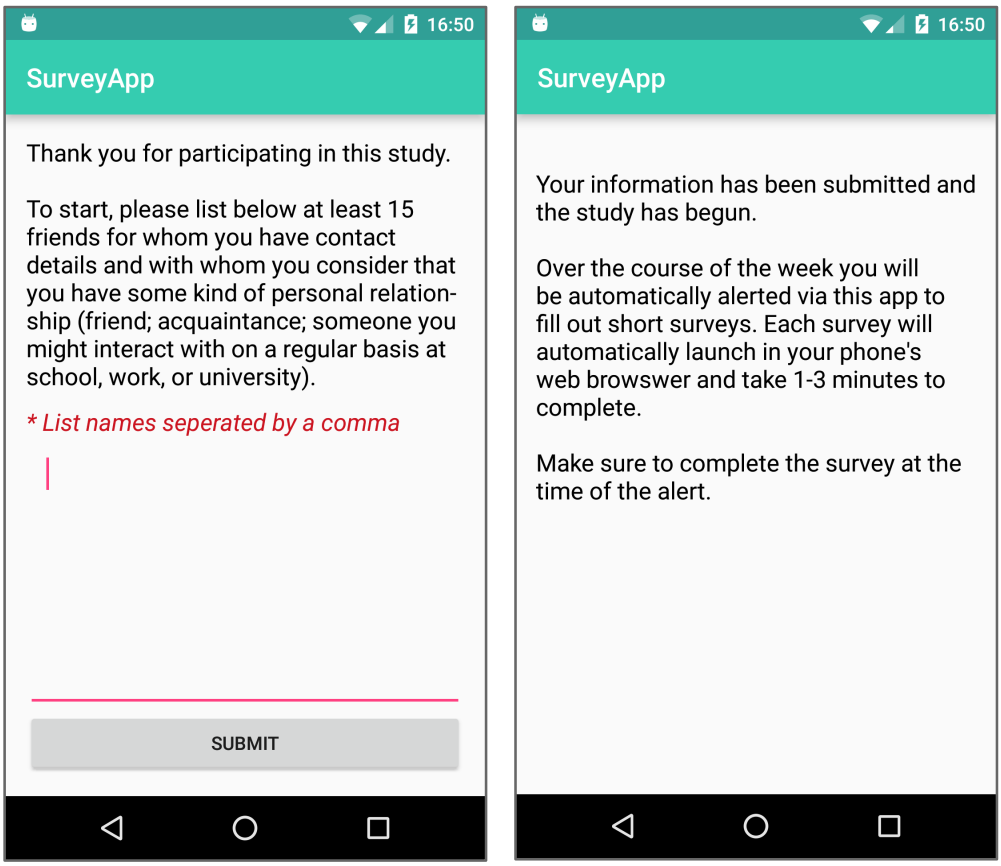

Fig. 3 Screenshots of SurveyApp UI screens

The submitted data is then stored with variable names and programmed into dynamic URLs. In Android devices it is possible to set up notifications, which sends notifications to users at specific times. These notifications can make the phone have an audio alarm, vibrate, create a blinking light, and create a small message to users. All of these were enabled in the notifications that were built in order to alert participants to record data by filling out a survey. To try to get the user to fill out the

survey right away instead of ignoring the notification, it was set up so that the dynamic URL would automatically open in the mobile phone's web browser upon unlocking the phone when one is responding to the notification alerts. As a fall back, in the scenario that a participant had missed the alert, it was also set up to do the same action if the participant tapped on the notification alert the next time they unlock their phone. These notifications were set to alert the participants at set times for 7 days; 9:00, 12:00, 17:00, and 21:00. Because the notifications would be interrupting participants, these times were chosen in an effort to be less intrusive and elicit responses right away as opposed to ignored notifications because a participant is busy (i.e. sleeping, at work or school, driving, etc.) Based on a typical work day where a person works 9:00 - 17:00, it seems useful to ask for information right when the day starts for participants, ends, and when they might be taking a lunch break. The survey sent at 21:00 asks participants for anyone they have contacted that day, even though it would make sense to ask this at midnight as that is truly the end of the day, but there is a high probability that participants are sleeping at this time and thus 21:00 was chosen to as to still record data while they are awake at the end of the day. An additional notification was set to go off as a final alert after 7 days to send the participant to an Exit Survey. This survey included the theory of mind tasks, social network size task, and asked for any feedback in regards to the study.

5. Mobile app: WhatsApp for iPhone. SurveyApp was built for this study, but was only available for participants using Android devices. As to not exclude other users from the study, it was possible to use WhatsApp to send notifications manually in the form of an IM message. These messages could contain the URL to the online surveys, and the built in IM notification system from WhatsApp could be used. The only difference for participants using WhatsApp would be that the URL would not automatically open in the mobile phone's web browser and the audio alert would not be as long as the alerts found in SurveyApp. The information collected by the Android mobile app was transferred to the online survey titled *SurveyApp: Start Data*. The data exported from this survey was in an Excel spreadsheet and dynamic URLs were created within the file using macros formulas. These dynamic URLs were then sent manually to participants at the same set times as the Android app users.

It would be quite some work to repeatedly send customized URLs to participants multiple times a day, so an automated approach was explored. An Android app called Seebye Scheduler was used to schedule recurring WhatsApp messages to participants. The app works by syncing with WhatsApp on a phone and automatically sending messages. The recipient, message, date, and time are pre specified. This was a more time efficient approach than sending individual messages, and hence was used to send WhatsApp messages.

WhatsApp can only send messages to phone numbers in currently listed in the address book of mobile phone. So in order to set up the use of scheduled WhatsApp messages, the mobile numbers of the participants (received through the Invitation to Participate survey) were manually added to the smartphone being used to distribute messages to WhatsApp users. Then, WhatsApp messages for each participant were scheduled through *SeeBye Scheduler*. A total of 5 messages are scheduled for each participant, four of which are recur daily. Each message was prefaced with "Good morning! Please fill out your survey here: URL link", whereby morning would be replaced with afternoon and evening in accordance to the set time of day the survey is sent. Because there are 15 URL variables added to the end of the online survey's URL link, the links become quite long, so they were manually shortened using Bit.ly (See Fig. 4).

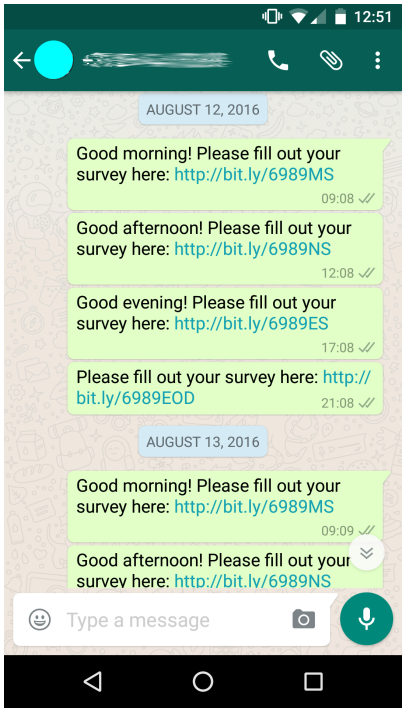

Fig. 4 Screenshot of WhatsApp Messages using Bit.ly links

D. Pilot Procedure

An online survey titled *Invitation to Participate* was distributed on Facebook as a public post in a few group pages and on one personal Facebook Page. The *Invitation to Participate* survey described to potential participants that the study was for the duration of one week and would require a mobile phone that is used daily which connects to the internet via Wi-Fi, 3G, or 4G and their cooperation for one week. Cooperation was defined in the information as requiring the participant to download a supplied mobile app to the participant's phone, fill out short online surveys (1-2 questions each) throughout the week when the phone alerts them to do so, and to complete an Exit Survey at the end of the study. Furthermore, it stated that the downloaded app would automatically send notifications to their phone throughout the week asking them to fill out the surveys, and the surveys would automatically open in the phone's web browser when the notification is sent to the phone. Additionally, an incentive was offered to participants. All participants who completed the study, and opted to be considered, had a chance to receive a gift card of 25 (Euros or US Dollars), of which one would be selected randomly for the prize. Basic demographic questions were asked (age and gender)

as well as an email address and phone number. Participants were asked to select the operating system of their phone (Android, iOS, or other) and if they used WhatsApp or Facebook Messenger apps on their phones.

Participants who filled out the form whom identified their mobile phone with an Android Operating System were emailed instructions on how to download a mobile app called SurveyApp to their phone and how to start the study. SurveyApp automatically sent alarms and notifications to participants when an online survey should be filled out, as well as opening the online survey in the mobile phone's web browser. All other participants subsequently identified their mobile phones as iOS and used the IM app WhatsApp. These participants were emailed instructions on how to start the study with the use of WhatsApp as a means to receive their alerts to fill out surveys, and a URL link to an online survey titled *SurveyApp: Start Data*. This survey was used to collect the names of 15 friends to be used as URL variables. A mobile app called SeeBye Scheduler was used to manually schedule automatic WhatsApp IM messages to participants. These messages were used as a notification alerting participants when to fill out surveys, with a URL link to the online survey.

After 7 days of receiving motivation surveys, all participants received a notification to fill out an Exit Survey. The Exit Survey contained the Theory of Mind and social network size tasks, respectively. Approximately four weeks after the end of the initial study, participants were asked to complete an adapted version of the initial social network size task because results of the original task revealed too much noise. An adapted social network size task was given to participants as an online survey that was distributed to participants through email.

V. Results

For each motivation survey, participants reported motivation values for 15 people. An average motivation value was calculated for each person, and the values were then used to calculate an average motivation score for each participant. We obtained two Social Network Size (SNS) samples, one from a list of names of social contacts in the past 7 days and the other for the past 30 days. The sum of each provided us with a total 7 day and 30 day SNS score. The adapted SNS task was calculated the same

way, but was only completed by 21 participants. Theory of Mind scores were calculated by the amount of questions they answered correctly divided by the total amount of questions.

Using the total average motivation score, social network size (SNS) data sets (7 and 30 Day), and theory of mind values, a hierarchical regression was conducted to see if motivation and Theory of Mind capabilities correlated with the sizes of social networks. The regression was executed two times, once with the original SNS data and again with the adapted SNS data. Table 1 shows a correlation matrix for both original and adapted SNS data. Table 2 is the descriptive statistics of variables.

Table 1. Correlation Matrix

Original SNS Task	**Motivation**	**ToM**	**SNS 7 Day**	**SNS 30 Day**
	24.31333333	0.483871	20	30
24.31333333				
0.483871	0.241374321			
20	0.123887551	0.244959126		
30	0.41859787	0.143645771	0.347718514	

Adapted SNS Task	**Motivation**	**ToM**	**SNS 7 Day**	**SNS 30 Day**
	24.31333333	0.483871	37	35
24.31333333				
0.483871	0.208038891			
37	0.157258715	0.581243325		
35	-0.142522262	0.322312253	0.303305863	

Table 2. Descriptive Statistics of Variables

	Original SNS Task (N = 21)				*Adapted SNS Task (N= 20)*			
Variable	**Mean**	**S.D.**	**Min**	**Max**	**Mean**	**S.D.**	**Min**	**Max**
Motivation	13.99	10.50	1.96	31.35	13.38	10.71	1.96	31.35
ToM	0.75	0.16	0.24	0.95	0.75	0.16	0.24	0.92
SNS - 7 Day	15.52	7.61	4	34	14	9.10	1	37

SNS - 30 Day	13.14	11.55	1	45	13.15	10.16	2	35

The hierarchical regression performed with the original SNS data found that motivation and Theory of Mind capabilities did not explain a significant amount of the variance in social network sizes when sampled with the SNS 7-day data ($F(2, 18) = .406$, $p = .672$, $R^2 = .043$, $R^2_{\text{Adjusted}} = -.063$). Analysis of the SNS 7-day data shows that motivation did not significantly predict social network sizes (*Beta* = .111, $t(20) = .475$, $p = .640$), and Theory of Mind skills did not significantly predict social network sizes (*Beta* = .162, $t(20) = .696$, $p = .495$). Using the SNS 30-day data, results were similar finding that motivation and Theory of Mind had no significant amount of variance in social network sizes ($F(2, 18) = 1.953$, $p = .171$, $R^2 = .178$, $R^2_{\text{Adjusted}} = .087$). Again, motivation (*Beta* = .428, $t(20) = 1.976$, $p = .064$) and Theory of Mind capabilities (*Beta* = -.052, $t(20) = -.242$, $p = .812$) did not significantly predict social network sizes.

The original SNS data was then substituted with the adapted SNS data and the hierarchical regression was performed again, which also resulted in no significance in variation of social network sizes due to motivation and Theory of Mind capabilities for both the SNS 7 day ($F(2, 17) = .978$, $p = .396$, $R^2 = .103$, $R^2_{\text{Adjusted}} = -.002$) and SNS 30 day ($F(2, 17) = .036$, $p = .964$, $R^2 = .004$, $R^2_{\text{Adjusted}} = -.113$) data sets. Data analysis found in Table 3 reveals that neither motivation or Theory of Mind capabilities do not significantly predict social network sizes.

Table 3. Hierarchical Regression Model - original & adapted SNS

	R	R^2	$R^2_{Adjusted}$	*B*	*SE*	*β*	*t*	*p*
Original SNS - 7 Day								
Step 1	.176	.031	-.020					.444
ToM				8.150	10.427	.176	.782	.444
Step 2	.208	.043	-.063					.672
ToM				7.476	10.740	.162	.696	.495
Mot				.080	.169	.111	.475	.640

Original SNS - 30 Day								
Step 1	.004	.000	-.053					.986
ToM				.290	16.087	.004	.018	.986
Step 2	.422	.178	.087					
ToM				-3.650	15.114	-.052	-.242	.812
Mot				.469	.237	.426	1.976	0.64
Adapted SNS - 7 Day								
Step 1	.207	.043	-.010					.381
ToM				11.414	12.717	.207	.898	.381
Step 2	.321	.103	-.002					.396
ToM				10.019	12.733	.182	.787	.442
Mot				.210	.196	.247	1.070	.300
Adapted SNS - 30 Day								
Step 1	.065	.004	-.051					.785
ToM				4.011	14.485	.065	2.77	.785
Step 2	.065	.004	-.113					.964
ToM				4.039	14.984	.066	.270	.791
Mot				-.004	.231	-.004	-0.18	.986

Although differences between average motivation scores over the course of the day were not the focus of this study, we examined if motivation scores were higher than others at a specific time of day. Reported motivation scores were averaged per person (15 for each participant) 3 times of day;

morning, afternoon, and evening. A total average motivation score was calculated for each time of day per participant. A paired-samples t-test was performed to compare differences in motivation averages for morning to afternoon, morning to evening, and afternoon to evening. There was no significant difference in motivation averages in the morning (M = 14.62, SD = 11.21) and afternoon (M = 14.32, SD = 11.25); $t(20) = 0.20$, $p = 0.84$, $d = 0.29$. Analysis reveals that morning (M = 14.62, SD = 11.21) and evening (M = 12.82, SD = 10.67), also do not have a significant difference ($t(20) = 1.44$, $p = 0.16$, $d = 1.80$). Lastly, the paired t-test found no significant difference in motivation averages between afternoon (M = 14.32, SD = 11.25) and evening (M = 12.82, SD = 10.67); $t(20) = 1.22$, $p = 0.24$, $d = 1.51$.

VI. Discussion

This pilot study was limited in self-reported data, the methods used to obtain data, and its relatively small sample size. In assessing if any correlations existed with motivation, social network sizes, and theory of mind capabilities no significance was found, given the methods used in this study.

A. Motivation

Motivation was assessed by participants as self-reported values from a sliding scale from 0 (not motivated) to 100 (very motivated). Some feedback from participants helps us understand how values were determined. Two participants said that the motivation values were a reflection of their contentment or discontentment with recent previous interactions. That is to say that they were more motivated to interact with someone whom they had recent positive experience with as opposed to someone they had a negative experience with. Participants also mentioned the alarms (from SurveyApp) were too annoying and interrupted their task at hand, which lowered their motivation to fill out the motivation survey. This effect could be working against the goal of this study and might be attributing to lower motivation values from participants. Interrupting participants throughout the day could also lead to participants ignoring notifications and hence attribute to higher participation dropouts. Missing data could also be from users who are unable to do complete the surveys at the

times they are notified and forget to do them later. This is unavoidable and expected as participants are participating in a non-controlled study.

Furthermore, participants were also asked to report motivation values 3 times a day at set times. We analysed the motivation averages for each time of day to see if there were any significant differences. Such information could be useful in designing future versions of this task by focusing on asking participants about motivation at certain times of the day. Results show no significant differences in motivation scores for the times of day surveys were sent out in this study; 9 am, 12pm, and 5pm.

Lastly, we investigated individual motivation as a separate independent factor of social network sizes. It still remains unclear if there are any relationships with individual motivation and social network sizes, but in our study motivation was investigated as an exclusive constraint. Motivation needs to be further researched to understand if it plays a limiting role in social network sizes, but it is also important to note that it is possible that motivation needs to be placed differently within the constraints. Perhaps motivation needs to be included within the constraint of time. For example, the ability to contact and interact with an individual could ultimately be due to time availability regardless of motivation.

B. Social Network Sizes

The social network size task from a previous study by Lewis et al., (2011) appears to be unreliable. This has been indicated by our results of large variations in the data, as well as through questions and feedback provided by the participants. Part of the problem seems to be how the task is set up, as it defines social contact as one-on-one interactions that can occur in multiple ways, but it fails to address and define interactions that occur through social media, specifically through Facebook, that are similar to the types of interactions described in the task. A few participants left feedback with uncertainty of social interactions through Facebook whereby they felt they had one-on-one social interaction by using the "like" function or posting a comment on a wall or photo (even though others can view these). In these scenarios the interactions are not in the form of a broadcast (i.e. sending a

tweet on Twitter, or posting a comment on your Facebook wall to all of your Facebook friends), but regarded as one-on-one interactions similar to writing an email or letter - which is listed as a form of social interaction. In the adapted version of this task the guidelines were stricter to account for only private one-on-one interactions. And although the guidelines for the task mentions excluding professional interactions, questions arose from a few participants regarding accounting for interactions with colleagues whom they had social interactions with while at work. The guidelines did not help participants understand these types of interactions. Other feedback pertained to not being able to remember all social contacts in the past 30 days. Some thought this was a memory test and mentioned they simply could not remember all interactions, even though the original task mentions that participants can use their address book to aid in the task. In the adapted version, we stressed the importance of accurate data and offered more ways to help them remember social interactions by scrolling through different mobile apps (Call log, SMS, IM chats, calendars, agendas, photos, and email). Still, it appears the results of the adapted version had too much variation. Additionally, it was observed that a few participants had excluded social interactions they had with me, which were not professional in nature. It is not known why, but perhaps it was because I was conducting the study or simply because they had forgotten. If it is the latter, how many others are forgotten? Furthermore, it is important to note that the original task was part of the Exit survey which contained the mentalising tasks first and the social network size task last. Participants gave feedback that the Exit survey was too long, which could have attributed to inaccurate social network size data due to low motivation to do more than what had already been done (7 days of motivation surveys and mentalising tasks). All of these cases contribute to inaccurate data, and although the task was performed by participants twice, results for both tasks reveal too much noise in social network sizes. Because of this, it is advised to use the full SNS questionnaire or find a more accurate short form version of the questionnaire to measure social network sizes in for future research. On a final note, the additional questions on the adapted SNS task used to identify if motivation averages were higher for listed romantic partners and family members compared to others in their personal list of friends showed no trend.

C. Theory of Mind

Participants' Theory of Mind capabilities were assessed using three multi-level intentionality tasks previously used by Kinderman, Dunbar, and Bentall (1998). Results reveal a normal distribution, but there are two important things to mention. First, feedback from a few participants revealed that the option "I don't know" was being used for answers that would have resulted in "False" rather than truly not knowing the answer. Second, it was also mentioned that some questions pertained to information that wasn't available in the given stories, which indicates that the Theory of Mind task needs improvement.

D. Use of Mobile Phones

The methodology applied to this study requires some technological and user experience dependencies that can unexpectedly affect the results. First, there is a major dependency on the mobile phones' ability to successfully connect to the internet for both groups of participants (SurveyApp and WhatsApp groups). In both groups, participants need an internet connection (Wi-Fi or 4G/3G) access in order to view and complete the online surveys versus storing data on the device and sending it in the background. Each time the participant receives a notification, four times a day, these elements must work. This dependency could be minimized by collecting and storing all data on the mobile device and only transferring the said data to a database when the phone successfully connects to the internet. In this approach app users would be able to successfully record data any time as opposed to the time their mobile phone can connect to the internet. Using WhatsApp to send notifications to participants is also reliant on the internet to send and receive notifications. In this scenario, it is possible that the participant does not receive the notification at the time the message was actually sent.

Secondly, Android mobile apps do not behave the same on every device because app developers independently choose the version of Android framework they want to develop for, known as the API level ("Android Developers," n.d.). The application uses the identified framework to interact with the underlying Android system ("Android Developers," n.d.). SurveyApp was initially built and tested on API level 23, which correlated to the most recent version of Android at the time of this study,

Marshmallow v6.0. Functionality testing for SurveyApp was executed on one Google device and two third party devices running the Marshmallow Operating System (OS), a very small sample size out of the many existing devices. According to Smith (2016), as of September 2015 more than 4,000 distinct Android devices exist, all of which run different versions of the Android OS. A few participants did not have compatible devices to download the app, so the API minimum level was lowered to 15 (Ice Cream Sandwich v4.0) to accommodate them. Once the API was lowered these participants were able to download the app, but unfortunately some did not receive any notifications. This could be due to code incompatibilities and device functionalities. Attempts to solve this would be to test functionality, go through bug reports, and debug for individual devices. Ultimately, this means participants might not receive all or any notifications.

Thirdly, individuals understand how to interact with their devices differently. Some are novice mobile phone users and others are not. This depends on how individuals use their device in their lives and how much experience they have with the use of the apps on the phone itself. As each app serves a different function and offers different interaction, individuals learn how to interact with apps over time. This study required the use of two mobile apps for each group, the phone's web browser and SurveyApp or WhatsApp. Although the process of the study was explicitly stated that online surveys would be used, this was not fully understood by some. A few participants thought the surveys would be within SurveyApp itself, and did not understand why the app would not open once they received a notification instructing them to fill out a survey. They did not understand that the survey would be launched in the web browser. Understanding how to work with the Android notification system was also not fully understood by some participants. The system wide notification functionality offers a notification message on a phone's lock screen and as an icon in the status bar of the phone. Once a phone is unlocked, the notification message on the screen disappears and some did not know how to access the message again. The app was coded to automatically open a web browser to a set URL once the phone is unlocked, to avoid this problem, but some devices did not function like this (due to the aforementioned API level or possible bugs). When functioning correctly, the URL is opened in the

web browser and all notification messages are canceled so they cannot be accessed. This was to prevent participants from getting a duplicate notification and filling out a survey they have already completed. Additionally, each URL that opened in a web browser would open in a new tab. After completing each survey participants are instructed to close the browser window to exit. Non novice web users did not fully understand how to close the browser window. When the tab and browser are not fully exited and a notification opens the web browser for the next survey, some participants' browsers would open the last tab they had open containing the previous online survey. This lead to confusion or thinking the app does not function correctly. These interactions and confusions could be a reason for incomplete survey results.

It is also important to note that the participants receiving notifications via WhatsApp, through scheduled messages sent from the app SeeBye Scheduler, also did not always receive all notifications. SeeBye Scheduler had some bugs and did not always function properly, especially in the hours from midnight until 8:00. During this time the app would crash or the phone would shut down, possibly from the app crash. It was observed that participants in other time zones, specifically within North and South America, did not receive some of their notifications.

VII. Conclusion

The aims of this pilot study were to investigate the following research questions: (a) Does motivation play a role in Dunbar's number? (b) What is motivation, and is there a relationship to social network sizes? and (c) How can motivation be operationalized in a study? We hypothesized that individual motivation played a role in individual social network sizes, thus individuals with higher motivation would have larger social network sizes, and possibly better Theory of Mind capabilities. Results are inconclusive as data analysis reveals too much noise in the social network size data, thus no determination of a rejected hypothesis. Further, improvement in how social network sizes are assessed and a larger sample size is needed to validate or reject the hypothesis. Additionally, motivation was operationalized in our study as surveys sent to mobile phones asking participants how motivated they were to interact with their friends. These motivation surveys were sent out three times

a day for the course of a week via mobile phones. It is unclear, at this point, if assessing motivation in this manner is successful, although it seems advantageous to use mobile phones to collect psychological data from within an individual's natural environment. Experience from this study suggests that interrupting people within their environment while they have other priorities can distort data collection. Also, the use of mobile phones creates a dependency on technology, user interaction, and the level of experience one has with these. This has to be taken into account when relying on mobile phones to collect data in future studies. Lastly, due to time and technical limitations, this pilot study used a hybrid app as a method to collect and record data, but an improvement to the method would be the use of an all-inclusive app that does not have a dependency on an internet connection every time participants are notified to fill out a survey.

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