ABSTRACT
Previous research reports a number of different variables that affect group processes. We examine situations in “triple space,” in which people must manage (1) complex problem-solving tasks, (2) social interaction, and (3) the meaning making process of the changing representation created by others on shared mediums. In this case, the complex problem-solving task is solving a shared Sudoku puzzle. Two findings follow from the current study. People in both the laptop and tablet conditions talked less than people in the paper-control condition, but only people in the laptop condition experienced a significant decrease in positive emotion.

Author Keywords
Micro-coordination; Coordination; Form Factor

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Questions such as “would you feel more positive if you played a crossword puzzle with your friends on an iPAD as compared to playing the same game as printed in a newspaper or with a laptop?” or “would you talk more if you played Settlers of Catan on a laptop rather than playing it on a tablet?” might sound absurd or obvious to some people. They might ask “why would people feel or act any differently by engaging in the same kind of activities using different forms of technologies?” or they might say “I know how to use technology, so it’s all the same to me.” Indeed, the person who expresses doubt might, in today’s culture, feel a need to apologize or qualify him- or herself as “not a technical person.”

Previous research, however, has shown differences in interactive technologies can affect and change users’ behaviors and their feelings toward the artifacts. For instance, people prefer a computer that flatters or diagnoses them as happy regardless of the correctness of the assessment [13]. People act politely towards computers in general [14], but not towards small computers [6].

In our study, unlike previous studies that looked at how people react to different interactive technologies, we investigate how mediating technologies affect people in group settings. In this case, we examine the role technological mediums play in influencing behaviors and emotional states in a “triple space” situation. Participants play a collaborative Sudoku game while in the same physical location. Baron [1] describes students solving a problem together as jointly inhabiting a “dual space” involving the management of both cognitive and social functions. Lee, Tatar and Harrison [10] have previously described the increasingly common situation shown in Figure 1 as representing a “triple space,” in which participants are managing not only the cognitive and social functions described by Barron, but also the challenge of making sense of the changes to the shared medium caused by the other players.

Figure 1. Interactions in Triple Space
Jean Twenge documents a rise in anxiety and depression among young adults, and argues that today’s children see themselves as solitary actors, untied to others in Generation Me [16]. Sherry Turkle also portrayed people in our current society as becoming more and more detached from face-to-face interactions and increasingly attached to machinery in Alone Together [15].

While a recent Pew Internet Personal Networks and Community survey reports that the extent of social isolation has not changed since 1985 [7], Klinenberg reports that more than 50% of American adults today are single and one out of every seven adults lives alone [9]. Klinenberg assesses this change positively, claiming that the rise in rates of living alone is a transformative social experience.
that requires us to make changes in how we view ourselves and our intimate relationships. He claims living alone does not make people any lonelier, and goes on to explain how solitude can be beneficial in reviving personal energy in a hyper-networked, always-connected culture [9]. Klinenberg does not provide evidence about unhappiness (more generally than loneliness).

While the evidence for whether Americans are becoming evermore isolated is still mixed and controversial, and the interpretation for whether the use of social media is supplementing or replacing traditional interpersonal connections is debatable, it is an undeniable fact that we are living in the era of information technology, and that we do not necessarily understand all the ways that information technology affects us. For example, loneliness and unhappiness are closely related concepts but they are not identical, and questions about both may vary according to precise details in the framework in which the questions or assessments are made. We need to understand more and our understanding needs to come from many perspectives and levels of analysis. Tablets and smartphones are rapidly taking the place of desktops and laptops. However, we do not yet know what it means to use tablets and smartphones in the place of desktops and laptops.

Lee, Tatar and Harrison’s investigation [10] suggested a more complex interaction between technology design and user experience than had emerged clearly in prior works. In particular, they found that proxies such as “amount of talk” or even “kinds of talk” proved poor indicators of the satisfactory nature of the system.

The current study explores the relation between talk, difference in the mediating technology and user’s emotional state. It asks “How does the mediating artifact affect people’s coordinative behaviors and possibly the way that people feel as they engage in joint activities?” It uses the same highly demanding Collaborative Sudoku task as in [10], but contrasts a Paper, a Tablet and a Laptop condition. It investigates whether and how the kinds and the form factors of mediating technology affect users’ behaviors and their emotional state.

THE STUDY
To explore the possibilities of the differences in mediating technology having impacts on people’s emotional states and behaviors, we asked groups of people to play Sudoku collectively on a 25 x 30.5 inch sheet (base-line, Paper Condition) and on two different form-configurations (Tablet Condition and Laptop Condition) of tablet PCs. In the paper condition (PC), researchers prepared the Sudoku game board manually on 25 x 30.5 inch sheets prior to the study and asked participants to solve the puzzles on that. In both computer conditions, groups were asked to collaboratively solve puzzles on specially designed multiplayer Sudoku software, Team Sudoku.

We made an explicit decision to use a type of computer that has a twist-and-swivel display so that we could configure the same computer both as a laptop and as a tablet. For the laptop condition (LC), mice were connected to the systems as the primary input devices, while for the tablet condition (TC), stylus pens were provided as the primary input devices. Keyboard input mechanisms were disabled in the systems to maintain compatibility between the laptop condition and the tablet condition in which keyboards are hidden under the laid-down screens, inaccessible to the users.

Clearly, there are many differences between the paper and the computer conditions that are consequences of the types of sharing that they enable. However, the differences between the LC and the TC include only the configuration and the input device.

Team Sudoku
Team Sudoku is a multi-user, parallel-distributed form of the Sudoku game. Sudoku presents the player with a 9x9 board with digits between 1 and 9 in some cells. The goal of Sudoku is to fill the board so that each of the nine columns, nine rows and nine distinct 3x3 blocks contain exactly one instance of each digit from 1 to 9. Games are differentiated from one another by the number and location of starting digits. In the computerized form, each distinct game initially contains digits that cannot be written over or changed except by starting a new game, and that are a different color (black) from those that are in play (green).

Team Sudoku provides users three distinct features for manipulating the board. A pen tool enables users to insert entries on the board, and a pencil tool allows users to tentatively mark possibilities (note-entries). Users can delete any entries on the game board with an eraser tool. Team Sudoku is a multi-user collaborative variation of Sudoku in which players have their own computers with their own copies of the shared game board. When one player fills in a number, erases a number, or uses an indicating tool, the results are promptly shared on all players’ screens.

Procedures
Players were recruited from the Psychology Participant pool at our university, and received extra credit for participation. The advertisement for participation had two components: that the study was about a collaborative game, and that participants needed to have played Sudoku before. Players played in groups of two or three.

The study was designed as a two-phased, between-subject experiment. In phase 1, participants were asked to fill out online questionnaires about demographics, prior experiences with Sudoku as well as five personality self-report inventories (Big Five [8], Circumplex Scales of Interpersonal Values [11], Circumplex Scales of Interpersonal Efficacy [12], Beck Anxiety Inventory [2] and Beck Depression Inventory [3]). When participants reported
that they did not have prior Sudoku experience, they were
directed to a web site that had both descriptions of the
Sudoku rules and sample Sudoku games.

Figure 2. Set-up for three Team Sudoku Players (Laptop
Condition shown).

In phase 2, participants were brought into a small room and
seated in close proximity to one another (Figure 2). They
were introduced to one another when they came into the
room. After the informed consent process, participants were
asked to fill out a pre-game questionnaire (Q1) including
questions about their experiences with the game and with
the other players, and also the 20-item Positive and
Negative Affect Schedule (PANAS) [17] that measures how
people are feeling in the moment. The groups were asked to
work together on two Sudoku puzzles, in an order counter-
balanced across groups. The groups were given 20 minutes
to work on each game. After each game, participants filled
out post-game questionnaires (Q2 and Q3), including
retaking the PANAS. In Q3, we also asked them to rate
how much they were satisfied with the group and the way it
worked together on a scale of 1 (not at all) to 7 (very
much). There was also a short discussion at the end of the
study. Video and audio recordings of all the game sessions
were collected as well as computer logs and screen shot
movies of the games. Transcripts of the talk were made
using a method modified from Chafe [4].

Participants
A total of 138 (75 female, 63 male) college students en-
rolled in the study, in 24 groups of two and 30 groups of
three. Participants’ age ranged from 18 to 41 (M = 19 SD =
2.28). 10 of 138 reported that their first language was not
English, but none appeared to have difficulty because of
this. Almost all the participants had prior experience with
Sudoku. 15 reported initially that they did not know the
Sudoku rules. But researchers confirmed that these 15
people were at least fully familiar with the Sudoku rules
when they came in for the on-site experiment. Overall,
participants reported playing Sudoku quite often (M = 5.35,
SD = 1.51) on a scale of 1 (rarely) to 7 (several times a
day).

If only two participants appeared at the agreed time, the
game was run with them, resulting in 24 groups of two. In
this paper, we address only the 30 three-person groups.

In this note, we focus on the data on mood change from the
PANAS questionnaires and how many times individuals
took turns in group conversation.

FINDINGS
How the form factor of a technological medium
influences participants’ emotions
The first mood state (PANAS) questionnaire was given
before the first puzzle (P1), the second between the first and
the second puzzle (P2), the third after the second puzzle
(P3). As usual, the sum of scores for the Positive Affect
(PA) items and the sum of scores for the Negative Affect
(NA) items were calculated for each PANAS test.
Difference scores were calculated to monitor the mood
changes after playing the first game (P1-to-P2), and from
the beginning to the end of the experience (P1-to-P3). P2-
to-P3 differences are not reported, but continue the same
trends.

No differences were found in across the study in NA.
However, as shown in Tables 1 and 2, there were significant
differences in the mean changes in PA by
 technological condition (from P1-to-P2, F (2, 87) = 5.05, p
< .01) in which PA scores showed a gain of the most
positive affect in the PC, a gain of only a bit in the TC, and
a loss in the LC. These changes became more differenti-
ated from one another after the second game (F (2, 87) = 7.68,
p = .001). Despite reaching statistical significance P1-to-P2,
the test of homogeneity of variances showed unequal
variances among the three conditions. However, the
Welch’s adjusted F ratio confirmed and even strengthened
the previous finding, (F(2, 55.32) = 5.46, p =.007). The
effect size for P1-to-P2, calculated using eta-squared, was
0.10 and for P1-to-P3, was 0.15. In Cohen’s terms, these
effects fall between medium and large. (p.284-287, [5]).

Drilling down, post-hoc comparisons using the LSD test
indicated that participants in PC had a significantly higher
rise in PA scores than participants in the LC (P1-to-P2,
Mean Diff. = 4.97; p < 0.01; P1-to-P3, Mean Diff. = 7.53; p <
0.01). They were quite a bit more happy with paper than on
the laptop. This is, perhaps, not very surprising. More
surprising were the differences between the TC and the LC.
While these were only marginally different from P1-to-P2
(Mean Diff. = 2.83; p = 0.07), they were significantly
different from P1-to-P3 (Mean Diff. = 4.43; p < 0.03).
Instead of, for example, Laptop and Tablet resembling one
another, Paper and Tablet were more aligned on this
outcome measure, although the difference neared
significance if examined from P1-to-P3 (P1-to-P2, Mean
Diff. = 2.13, p = 0.18; P1-to-P3, Mean Diff. = 3.10, p = 0.11).
Furthermore, the mean value for the LC (M = -1.23)
decreased after the first game, while the mean value for the
TC (M=1.60) and the PC increased (M = 3.73).
In other words, differences in people’s positive emotional states are associated with the properties of the medium, and these differences are associated not only with the large and obvious differences between the PC and the computer conditions, but also with the more subtle differences between the LC and the TC. The difference between the LC and the TC shows that not only the differences in mediating technology, but also the differences in form factor, affect people’s emotional states differently.

We also found a statistically significant positive correlation between the amount of talk and changes in individual’s positive emotion ($r=0.24; p=0.02$). As with reported satisfaction with the group, this overall condition was driven primarily by the paper condition ($r=0.45; p=0.01$), with weaker contributions from the other two (TC, $r=0.27$, $p=0.15$; LC, $r=0.25$, $p=0.18$).

**DISCUSSION & CONCLUSION**

Our results show statistically significant differences in the amount of talk among the conditions. People talked more when they shared a big piece of paper to collectively work on a Sudoku puzzle. They talked significantly less when they were using computers. Our data also show that people’s positive feelings rose more when they talked more. And from those two findings, we might conjecture that the evermore prevalent use of technologies in current society might be holding people back from engaging in face-to-face conversations, which in turn might cause a rise in anxiety and depression among the young adults as documented by Twenge [16].

On the other hand, we also found that people who used tablets were less susceptible to the changes in positive emotions. When participants used laptops, they talked significantly less and had a considerable decrease in their positive feelings than people who used paper. But when participants used tablets, the changes in their positive feelings weren’t statistically different from the people in the paper condition, even though there were clear differences in the amount of talk between the two groups. We still do not decisively know why people using tablets had higher positive emotions than people using the laptop. However, the fact that these two groups of people used exactly the same computers, but in different form configurations hints to us that the form factor of technological medium might affect changes in people’s emotional states differently.

Among the noticeable behavioral differences between TC and LC was that some participants in TC tried to glance over other players’ screens during the sessions while none in LC exhibited such behavior. Even though, players shared the exact same information on their own screens, participants might have felt more connected by having a chance to physically share what is considered their private resource. This conjecture might also help in explaining the highest mean numbers in positive affect changes in PC, in which participants had a large shared resource. In LC, upright-positioned screens might have acted as physical barriers between players, whereas in TC, laid-down screens could have helped people to feel enhanced social presence by providing increased immediacy for social interactions [18].

Our findings are promising in the sense that the increasing use of tablets might alleviate the increasing rise in depression among young adults (if such a trend exists). They also suggest the importance of investigating the relationship between tablets and similar-yet-different form...
factors such as tabletops and smart phones. Indeed, we believe that comparing technologies with different screen sizes (tabletops, desktops, laptops, tablets in different sizes and mobile phones) will help us further test our hypothesis of having physically less obtrusive technologies increasing in positive emotional states. In this short paper, we have not advanced a theory of the relationship between these findings, but we point out that there may be important effects in an increasingly present situation. Form factor just might matter.

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