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ABSTRACT

Many families today use video chat to help their babies develop or maintain relationships with remote family members; however, there is very little existing research that systematically compares infant emotional engagement during face-to-face and video mediated interactions. A laboratory experiment was carried out with 49 infants between the ages of 6 and 12 months. Babies and mothers played peek-a-boo either face-to-face, via video chat, or via non-contingent video. Babies' engagement was indexed by smiling and looking time, and physiological activity was simultaneously recorded. Results showed similar levels of engagement across the three presentation conditions. Babies smiled just as frequently and gazed at their mothers for the same amount of time, and their physiological responses were indistinguishable. Their smiles were marginally quicker to appear when interacting face-to-face than via video chat. Furthermore, global estimates of maternal sensitivity during the interactions appear to play a greater role in eliciting positive responses from babies than the medium by which they interact. These findings and future directions are discussed.

KEYWORDS: VIDEO CHAT, PHYSIOLOGICAL RESPONSE, PEEK-A-BOO, VIDEO, CONTINGENCY, MATERNAL SENSITIVITY, INFANT ENGAGEMENT.

RÉSUMÉ

L'engagement émotionnel des nourrissons en vidéo-chat avec leur mère

De nombreuses familles utilisent aujourd'hui le chat vidéo pour aider leur bébé à développer ou à maintenir des relations avec des membres

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de la famille éloignés ; cependant, il existe très peu de recherches qui comparent de façon systématique l'engagement émotionnel du nourrisson lors d'interactions en face à face et par vidéo. Une expérience a été réalisée en laboratoire avec 49 nourrissons âgés de 6 à 12 mois. Les bébés et les mères ont joué à coucou soit en face à face, soit par chat vidéo, soit par vidéo sans contenu. L'engagement des bébés a été évalué par le temps passé à sourire et à regarder, et l'activité physiologique a été simultanément enregistrée. Les résultats montrent des niveaux d'engagement similaires dans les trois conditions de présentation. Les bébés sourient tout aussi fréquemment et regardent leur mère pendant le même laps de temps, et leurs réponses physiologiques sont différenciables. Les sourires des bébés apparaissent de façon légèrement plus rapide lors d'une interaction en face à face que lors d'un chat vidéo. Enfin, les estimations globales de la sensibilité maternelle pendant les interactions semblent jouer un rôle plus important dans l'obtention de réponses positives de la part des bébés que le moyen par lequel ils interagissent. Ces résultats et les orientations futures de recherche sont discutés.

Mots-clés : chat vidéo, réponse physiologique, coucou, vidéo, contingence, sensibilité maternelle, engagement du bébé.

Introduction

The accessibility and affordability of modern communication media have made it possible today for separated families to maintain contact with one another at a distance. For preverbal children, however, the options are limited. Studies have demonstrated that audio-only communication, like telephones, is not particularly effective for very young children (Tarasuik, *et al.*, 2013) and remains difficult for them to use even through age seven (Ballagas, *et al.*, 2009). Video chat offers an important alternative for families with young children, especially when they are preverbal, because it combines vocal and visual input to more completely approximate face-to-face communication. There is evidence to suggest that some families use video chat regularly with their babies and toddlers (McClure, *et al.*, 2015; Rideout, 2017), and that they are able to use it fairly successfully at home (McClure & Barr, 2017; McClure, *et al.*, 2017). It is unclear, however, whether babies are as emotionally engaged in these interactions as they are in face-to-face interactions. In the present study to examine this systematically, we conducted an experimental study directly comparing face-to-face and video-chat interactions.

Mother-infant face-to face interaction is known to be emotionally significant (Tronick, *et al.*, 1978), providing a strong test for comparison to video chat. Sensitive, contingent responses from mothers to their babies are known to play

an important role in both babies' social-emotional development (Stayton & Ainsworth, 1973; Grolnick, *et al.*, 1999) and more specifically in heightening babies' positive responses during social interactions (Stern, 1993). Furthermore, there is some evidence suggesting that babies under one year of age are emotionally sensitive to very subtle changes in contingency and reciprocity in their mothers' behavior (Murray & Trevarthen, 1985; Gusella, *et al.*, 1988; Nadel, *et al.*, 1999).

Prior research comparing infant emotional responses to their mothers on screen and face-to-face is limited. It has been demonstrated that presentations of events on screen do, indeed, have the power to affect babies emotionally, albeit with less intensity than events presented in-person (Diener, *et al.*, 2008). Furthermore, a comparison across still-face studies has shown that babies take longer to smile at their mothers when the procedure is presented via live video feed than when presented in the typical, face-to-face fashion (Gusella, *et al.*, 1988). Some older babies have also been shown to smile and attend more to their mothers when presented via live video feed than when presented in a video replay (Bigelow, *et al.*, 1996). Hains and Muir (1996, experiment 1), compared the responses of 5-month-olds to individuals in video mediated conditions. First, they examined how babies reacted to their mothers when they interacted as usual via contingent (i.e., live video feed) or non-contingent (i.e., pre-recorded) video. They found that there were no differences in the babies' visual attention or number of smiles towards their mothers in these screen conditions. This study revealed that babies may be tolerant of short periods of non-contingency from their mothers, whose interaction style is very familiar to them, so long as the mother continues to use her normal interactive style. This study, however, like others of this kind (Murray & Trevarthen, 1985; Nadel, *et al.*, 1999), did not include a presentation of the mother in a *live face-to-face* condition, so the results can only be interpreted for mothers presented on screens.

Hains and Muir (1996, experiment 2) conducted a second study, this time comparing babies' responses to presentations of a *stranger*, now in all three conditions (contingent video, non-contingent video, and face-to-face). Here, the infants were more visually attentive to both of the contingent interactions with the stranger (face-to-face and contingent video) than to the video replay version. This suggests that infants as young as 5 months have the ability to detect very subtle differences in contingency between these interactions. While these infants had an equal level of visual attention to both the face-to-face and the contingent video, infants smiled earlier (as in Gusella *et al.*, 1988) and more often in the face-to-face interaction, indicating a more positive response to strangers they interacted with in-person than on screen. While Hains and Muir (1996, experiment 2) has the advantage of comparing all three conditions side-by-side, the study uses a stranger rather than the mother for the interaction.

The Present Study

The present study extended the Hains and Muir (1996) studies in four ways.

1) Hains and Muir (1996) used strangers instead of mothers in their second experiment, in the present study mothers will be used instead.

2) Prior studies (Hains & Muir, 1996) used a repeated measures design which may have been subject to order effects due to babies' reduced interest in the interaction across time. This study will employ a between subjects design.

3) Hains and Muir (1996, experiment 1) allowed mothers to interact as usual with their babies, which likely introduced non-systematic variation in the interactions. Following Diener *et al.* (2008), the present study will use a more precisely defined peek-a-boo interaction procedure. Peek-a-boo was chosen for several reasons. First, it is developmentally appropriate for infants under 1 year. During structured interactive games like peek-a-boo, infants demonstrate a growing understanding of contingency and display behaviors that indicate engagement and enjoyment (Miller & Commons, 2007; Parrot & Gleitman, 1989; Roggman, 1991). Second, by 5.5 to 6 months of age, infants have the working memory ability to be able to participate accurately in a peek-a-boo game (e.g. they anticipate correctly that the face will show up again in the same location as before; Reznick, *et al.*, 2004); and by 6-8 months, infants not only have specific expectations about peek-a-boo, they also smile less when it doesn't meet those expectations (Parrott & Gleitman, 1989). By 6 months, infants engage in peek-a-boo games as indicated by responding via smiling, making eye contact, and sometimes vocalizing (Nomikou, *et al.*, 2017) and these behaviors remain the most frequent behavioral responses between 6 and 12 months (Miller & Commons, 2007). Despite frequent imitation of other actions between 6 and 12 months (e.g. Nadel & Corbett, 2014), initiating the peek-a-boo game and copying the face covering gesture does not typically emerge until 12 to 15 months and even then is quite infrequent (Miller & Commons, 2007; Rome-*et al.*, 1995). Third, mothers have been shown to effectively modulate peek-a-boo to engage their babies as they develop additional skills and responsiveness between 6 and 12 months of age (Gustafson, Green, & West, 1979).

4) Prior studies, including Hains and Muir (1996), used observational measures of emotional behavior. The current study added measures of physiological reactivity, specifically skin conductance levels, heart rate, and respiration rate (Boiten *et al.*, 1994; Levenson, 2003). Both skin conductance and cardiac measures are used regularly to assess adult reactivity to digital media presentations (Ravaja, 2009), and have previously been used with infants (Hernes *et al.*, 2002; Ham & Tronick, 2008; Lansink & Richards, 1997).

In the present U.S. study infants' emotional responses to their mothers, presented face-to-face, via contingent video chat, and via non-contingent pre-recorded video, were compared. We examined 6- to 12-month-olds' responses during the peek-a-boo interactions, behaviorally examining the frequency of

eye contact and smiling behaviors and physiologically examining their skin conductance, respiration, and cardiac responses. The following hypotheses were tested:

Hypothesis 1: Following Hains and Muir's (1996) second experiment and the work of Bigelow and colleagues (1996), it is hypothesized that the use of a highly engaging peek-a-boo procedure will result in babies paying more attention to their mothers and smiling more face-to-face and via video chat than they do via non-contingent video; and that their patterns of physiological activity will reflect this heightened emotional reactivity. An alternative hypothesis, following Hains and Muir's (1996) first experiment, is that there will be no differences in babies' emotional reactivity to their mothers in the two screen conditions, as reflected in equal amounts of smiling and physiological activity across the groups; there will also be equal levels of attention across groups.

Hypothesis 2: As in Gusella, *et al.* (1998), we predict differences in latency to smile. Specifically, infants will smile earlier during the face-to-face interaction with their mothers than in the screen conditions.

Hypothesis 3: Given the strong relationship between maternal sensitivity and infant social-emotional responsiveness, it is expected that the mother's sensitivity will be an important predictor of the baby's emotional reactivity, as reflected in the number of baby smiles and in their patterns of physiological activity.

Method

Participants

Forty-nine infants between the ages of 6 and 12 months, their mothers, and a familiar second caregiver were recruited for what was described as a "peek-a-boo study" from the *Washington DC*-area via flyers, listservs, community events, and word of mouth. The second caregivers were fathers (82 %), grandmothers (10 %), nannies (4 %), a close friend (2 %), and a mother (2 %). The babies' mean age was 8.9 months (SD = 1.86), 45 % were female, and 61 % had previous experience using video chat (defined as having used it once a month or more). Fifteen additional infants (23 %) were tested but were not included in the final sample due to crying within the first minute of the interaction period (n = 9), experimenter error or equipment malfunction (n = 4), and parent error (n = 2). The present study's attrition rate is consistent with others that use physiological measures with infants, which often have rates of attrition and missing data above 20 % (Lansink & Richards, 1997).

Apparatus

Baby interaction booth. An interaction booth for the study was designed following Diener *et al.* (2008). Babies faced a black, foam-board display booth, set on a table at roughly eye level and 4 feet away from the baby (Figure 1). The

booth had a 10" x 16.5" opening in it, in which both the face-to-face and video interactions were presented: For the video interactions, a 19-inch, black, flat-screen monitor was placed just behind the opening; for the face-to-face interactions, mothers sat on a 9-inch tall stool, placed such that her face was 30 inches away from the opening. Above the opening was a small rectangular hole, in which a black web camera was placed to record the babies' behavioral responses and transmit them to mothers in the video chat condition. On either side of the opening, black speakers were placed behind a small rectangular hole, to allow the mothers' audio feed to be heard by the babies in both screen conditions. On the opposite side of the booth from the baby, a black poster curtain was used by an experimenter to cover the opening prior to the interaction period; this curtain was lifted to signal the beginning of the interaction period, and then dropped again to signal the end of the interaction.

Figure 1.
Baby interaction booth. Top left: Father and baby sit facing the interaction booth with curtain down. Top right: Baby's point of view, facing the interaction booth with curtain down. Bottom left: View of a model playing peek-a-boo in the face-to-face condition *(reenactment)*. Bottom right: View of a model playing peek-a-boo in the screen conditions *(reenactment)*.

Mother interaction booth. For the two screen conditions, the mother was located in a separate, adjoining room from her baby, and used a specially designed booth for the interaction (Figure 2). Mothers faced a black, foam-board booth, which was lined with sound-absorbing foam material to prevent her

voice from being audible in real-time to her baby in the next room. Within the booth was a 19-inch, black, flat-screen monitor, upon which a black web camera was placed to record the mothers' behaviors and transmit them to the baby. The mother sat in a chair located such that the camera was 30 inches away from her face, a position that produced an image of the mother than was equal in size, from the babies' perspective, to the mothers' faces in the face-to-face condition. A white noise machine was placed near the shared wall between the adjacent rooms, which was activated for the duration of the experiment to prevent the mother and baby from hearing one another through the wall.

Figure 2.
Mother interaction booth. Left: mother plays peek-a-boo in the video chat condition *(reenactment)*. Right: Mother prepares to play peek-a-boo in the video condition, facing a photograph of her own smiling baby *(reenactment)*.

Measures

Physiological measures. A system consisting of a computer, AcqKnowledge 3.9.1 software (Biopac Systems, 2009), and bioamplifiers (Biopac Systems) was used to obtain continuous recordings of the babies' physiological reactivity.

To measure heart rate, electrodes were placed in a bipolar configuration on opposite sides of the chest. Heart rate was measured in beats per minute. To measure skin conductance level, a procedure adapted from Ham and Tronick's (2008) method for collecting skin conductance in infants was used. A constant-voltage device passed a small voltage between electrodes attached to the plantar surface of the foot (on the heel) and on the infant's thigh. Skin conductance level was measured in microsiemens. To measure respiratory rate, a respiration belt was placed around the upper torso. Respiratory rate was measured in respirations per minute. AcqKnowledge software extracted raw data and produced wave-form transformations, peak detection, and graphic display for each channel. A sustained lower heart rate has been shown to indicate sustained attention in babies between 6 and 12 months (Lansink & Richards, 1997), while increased heart rate and skin conductance indicate greater arousal (Hernes *et al.*, 2002).

A trained research assistant removed artifacts from the data and calculated averages for the baseline and interaction period of the experiment. The average during baseline was then subtracted from the average during stimulus to create change scores, and all analyses of the physiological data were conducted using these scores. Due to equipment malfunction during data collection of skin conductance activity for some infants, the sample size for skin conductance analyses was smaller than that of the other analyses considered (n = 36).

Infant Temperament Questionnaire. Infant temperament was assessed using the *Infant Behavior Questionnaire – Revised, Very Short Form* (Putnam *et al.*, 2014), which is a parent-report measure designed for infants between the ages of 3 and 12 months of age. The 37-item form measures three components of infant temperament – Positive Affect, Negative Affect, and Orienting – using questions about the baby's behavior during the past week. The questionnaire took mothers approximately 5 minutes to complete.

Design

Mothers were randomly assigned to play peek-a-boo with their babies in one of the following three conditions:

Face-to-face: 30 seconds prior to the beginning of the interaction period, the mother was silently escorted into the room where the baby was located, on the opposite side of the curtain and booth from the baby so she could not be seen. A video camera on a tripod behind the baby's right shoulder recorded the mother's face during the interaction, and a webcam in the booth setup recorded the baby's face.

Video chat: The mother sat at an interaction booth in an adjacent room, facing a computer monitor with a web camera above it. The use of nonintrusive ear buds allowed her to hear the baby. The web cameras in each booth were used to both transmit and record the images of the mother and baby to one another. Prior to the interaction period, a black curtain obstructed both the baby's and mother's views of one another. This curtain was raised as a signal to the mothers to begin interacting.

Video (non-contingent): The mother sat at an interaction booth in an adjacent room, facing a computer monitor with a web camera above it. Mothers wore nonintrusive ear buds in this condition to maintain uniformity with the video chat condition; however the ear buds only played white noise. Web cameras recorded both the mother's and baby's faces, while also transmitting the mother's image to the baby's monitor. The mother's computer monitor was turned off for the duration of the experiment; however, a printed 4" x 6" photograph of her smiling baby, acquired prior to the study, was placed on the monitor at the same location where the baby's face would appear on the screen in the live video feed condition. Mothers were instructed to play peek-a-boo with their child while looking at and engaging with the photo before them. The mother held the end of a piece of yarn, which was connected to the setup

in the adjacent room, in her left hand while waiting to begin; she was signaled to start interacting by a tug on the yarn.

Procedure

Parents were sent one of three instructional videos, based on their condition, prior to the study. Upon arrival at the facility, mothers and babies were separated and escorted into two adjacent rooms for the warm-up and instruction periods. A brief distraction task was used to minimize infant anxiety during separation, and the second caregiver remained with the baby throughout the entire procedure.

Baby procedure. A researcher spent up to 10 minutes warming up with the baby by playing with toys and books on the floor of the lab space. During this time, the researcher also obtained informed consent from the second caregiver. After the warm-up period, the baby was seated on the lap of the caregiver for the duration of the experiment. The researcher then positioned the respiration belt and placed the cardiac and skin conductance electrodes appropriately. The procedure typically took less than 5 minutes.

The baby and second caregiver then sat quietly, with the baby sitting on the caregiver's lap, for 90 seconds to establish the baby's baseline physiological activity. Because babies were unable to stay still and content for this period without any stimulation at all, babies were provided with a small, relatively non-stimulating toy (a block, a cup, or a small book) to hold during the baseline period. The caregiver was instructed to stay quiet and still throughout the baseline period, only interacting with the baby (using a gentle method like mild rocking or humming) if the baby began to fuss.

After the baseline period, the curtain was lifted by the researcher, and babies saw their mothers playing peek-a-boo for 2.5 minutes; this period was truncated if the baby began fussing continuously ($n = 5$). The minimum interaction time was one minute. Babies that began crying prior to one minute were dropped from analysis. The second caregiver holding the baby was instructed to remain still and quiet during the interaction period, reacting neither to the mother's presentation nor to the baby's responses.

Mother procedure. During the baby warm-up period, informed consent was obtained from the mother and she was given instructions in an adjacent room. The mother was instructed to begin playing peek-a-boo with her baby immediately when the curtain was lifted (or when the yarn was tugged, see section *Design*) in whatever way she normally would at home. A black handkerchief was provided as a prop, but the mother was instructed to use it only if she and her baby would normally use props like these at home.

At the conclusion of the interaction period, the mothers and babies were reunited for a short play period, during which the mothers completed the infant temperament questionnaire and the families were fully debriefed about the purpose of the study. Babies received a small toy and certificate to take home, and families were compensated $15 for their time and travel.

RESULTS

Behavioral Coding

Two coders were trained to identify behaviors of interest for the study. The coders were not informed of the hypotheses of the study; however, given that the videos of mothers in the face-to-face condition were, of necessity, recorded at a different angle (i.e., from behind the baby's shoulder rather than from directly head-on, as with the web camera), experimental differences could not be completely hidden.

Both coders coded 22 % of the recordings for reliability purposes, and an overall inter-rater reliability of ICC = 0.95 or higher was attained. Any behavior that did not appear in at least fourteen sessions was dropped from all further analyses. After reliability was reached, each coder was responsible for coding 50 % of the recorded sessions. The total frequency or duration of each behavior per session was calculated.

The code definitions and their corresponding interrater reliability coefficients, reported as intraclass correlations (ICC), are presented below.

Baby: Number of smiles. Smiles were defined as when the corners of the baby's mouth were pulled upward, not just laterally (as defined by Ekman & Friesen, 1978 ICC = 0.95).

Baby: Latency to smile. The duration from the start of the interaction period (signaled by the lifting curtain) to the first infant smile. ICC = 0.99.

Baby: Maximum negative affect. The maximum intensity of the baby's negative vocalizations was assessed once for the baseline period and once for the interaction period using Braungart-Ricker & Stifter's (1996) 5-point scale: 0 (no negative vocalizations); 4 (shrieking, hysterical crying). ICC = 0.99.

Baby: Attention. The baby's attention was defined as whether the baby's gaze was directed at the mother/screen or not (eyes on / eyes off), as assessed using the web camera directly above the opening in the booth. The total duration of "eyes on" was summed to create the total duration of baby attention per session. The number of times the baby's eyes turned away and then returned back to the mother or the screen was summed to create an index called "distractibility". ICC = 0.98.

Mother: Intentional facial occlusions. The incidence and duration of events in which the mother intentionally hid her face for playing peek-a-boo was recorded. Occlusion was defined as when the mother put her hands together in front of her face, used the handkerchief to obstruct her face, intentionally moved beyond the baby's view to hide (usually laterally), or otherwise deliberately hid her face for the game. $ICC_{number\ of\ occlusions} = 0.99$, $ICC_{duration\ of\ occlusions} = 1.00$.

Mother: Unintentional facial occlusions. In the two screen conditions, mothers occasionally disappeared from view unintentionally (Figure 3) by leaning outside the camera view (usually by leaning forward, below the camera). The unintentional nature of these occlusions was often signaled by their inappropriate timing (e.g. the mother pops out from behind her hands [an intentio-

nal occlusion], but leans so far forward upon popping out that she moves below the camera view). Both the incidence and duration of these events were recorded. $ICC_{number\ of\ occlusions} = 1.00$, $ICC_{duration\ of\ occlusions} = 1.00$.

Figure 3.
Unintentional facial occlusion.

Mother: Latency to hide for the first time. We recorded how long it took for the mother to start the first round of peek-a-boo in seconds. In other literature this has been termed the preparation phase (Nomikou *et al.*, 2017). This variable was calculated by subtracting the time point at which the mother first intentionally hid her face (see variable "Mother: Intentional facial occlusions") from the time point at which the stimulus period began with the curtain raising.

Mother: Sensitivity. The mother's sensitive behavioral style during the interaction period was assessed using the *Parental Sensitivity Scale* from *The Emotional Availability Scales, abridged Infancy/Early Childhood Version* (Biringen, Robinson, & Emde, 2000). Coders provided a single score (between 1 and 9) for each mother, which indexes a global behavioral style of sensitivity. A global scale was necessary because mothers in the non-contingent video condition could not respond contingently, due to their inability to see or hear their children. They were, however, able to demonstrate a globally sensitive behavioral style, which includes factors like affect, authentic interest, and playfulness. ICC = 0.99.

Preliminary analyses

First, the characteristics of the babies in each condition were assessed for systematic, non-experimental differences (Table 1). There were no differences

in age, gender, video chat experience, maternal sensitivity, infant temperament, fussiness, or interaction duration across the three conditions. These variables were not considered further.

Table 1
Tests for non-experimental group differences

	Video Chat $n = 15$	**Video** $n = 16$	**Face-to-Face** $n = 18$	**Test Statistic**
Age	$M = 9.3$ $SD = 1.5$	$M = 8.9$ $SD = 1.8$	$M = 8.6$ $SD = 2.2$	F (2,47) = 0.60
Gender (female)	47 %	56 %	33 %	X^2 (2) = 1.83
Video Chat Experience	60 %	56 %	66 %	X^2 (2) = 0.40
Mother Sensitivity	$M = 8.1$ $SD = 1.2$	$M = 7.6$ $SD = 1.0$	$M = 7.9$ $SD = 1.2$	F (2,46) = 0.65,
Temperament				
Positive Affect	$M = 5.1$ $SD = 0.6$	$M = 4.8$ $SD = 0.6$	$M = 5.2$ $SD = 0.8$	F (2,46) = 1.19
Negative Affect	$M = 4.0$ $SD = 1.1$	$M = 4.0$ $SD = 1.0$	$M = 4.0$ $SD = 0.8$	F (2,46) = 0.00
Orienting	$M = 5.0$ $SD = 0.9$	$M = 4.9$ $SD = 0.6$	$M = 5.0$ $SD = 0.5$	F (2,46) = 0.08
Number of Fussers	27 %	6 %	28 %	X^2 (2) = 2.94
Interaction Length	$M = 156.4$ $SD = 22.6$	$M = 153.6$ $SD = 30.1$	$M = 158.2$ $SD = 26.9$	F (2,46) = 0.13
Transmission Delay	33 %	50 %	--	X^2 (1) = 0.88
Unintentional Occlusions Incidence Duration (seconds)	M SD 7.5 10.3 15.8 23.3	M SD 1.4 5.5 2.4 9.3	-- --	t (21.1) = 2.04$^+$ t (18.1) = 2.08$^+$

$^+$ marginal, $p < .10$; $^*p \leq 0.05$; ** p 0.01; *** $p \leq 0.001$

Preliminary ANOVAs investigating the babies' age and video chat experience were conducted. Video chat experience was originally measured on a 6-point scale assessing frequency of use (ranging from "Never" to "At least once a week"), but for purposes of statistical power was collapsed here into a dichotomous yes/no variable, with experience being defined as using video chat at least once per month, and no experience as using video chat a few times per year or less. These analyses yielded no main effects or interactions; therefore these variables were eliminated from the following analyses.

The screen conditions included two characteristics unique to their setup: unintentional facial occlusions, and the occasional delay in the transmission of the audio or visual input (< 5 ms) during the interaction. There were no differences in the number of sessions that had a transmission delay

between the screen conditions. There was no difference in unintentional occlusions between the two screen conditions (incidence: $p = 0.05$; duration: $p = 0.05$). Due to the marginal nature of this test, however, all applicable analyses were conducted both with and without the duration of unintentional occlusions as a covariate. This covariate did not affect the outcomes of any of the tests, so all analyses are reported without the covariate included.

Physiological activity

Next, we conducted a preliminary analysis to determine whether the peek-a-boo interaction was an effective manipulation between the baseline and the interaction period. We used a one-factor repeated measures (Experimental Condition X Period [Baseline, Interaction]) MANOVA on the three physiological variables. Analyses revealed a significant effect of Period, F (3,29) = 5.58, $p < .01$. This effect was driven by a significant decrease from baseline to interaction period for heart rate, F (1,40) = 7.17, $p = 0.01$, and a significant increase from baseline to interaction period for skin conductance, F (1,32) = 6.73, $p = 0.01$. There was no difference in respiratory rate between baseline and interaction period, F (1,40) = 0.25, $p = 0.62$.

Hypothesis 1: Smiling, Attention, and Psychophysiology

Based on Hains and Muir's (1996; experiment 1) findings, we hypothesized there would be no difference in how much babies smiled or attended to their mothers in the two screen conditions, as reflected in equal amounts of smiling and looking time and similar levels of physiological responsiveness across the groups.

A one-way ANOVA was used to examine frequency of smiling across the three conditions and revealed that there was no difference in the number of infant smiles across the video chat ($M = 4.86$, $SD = 4.45$), video ($M = 7.53$, $SD = 6.36$), and face-to-face ($M = 7.18$, $SD = 5.93$) conditions, F (2,43) = 0.95, $p = 0.40$, $^2 = 0.04$.

A one-way ANOVA was then used to examine attention levels across conditions. It also revealed that there was no difference in the duration of attention (in seconds) across the video chat ($M = 136.32$, $SD = 23.92$), video ($M = 140.01$, $SD = 28.51$), and face-to-face ($M = 132.41$, $SD = 33.11$) conditions, F(2,46) = 0.29, $p = 0.75$, $^2 = 0.01$. There was also no difference in the distractibility of the babies across the video chat ($M = 7.80$, $SD = 6.07$), video ($M = 6.06$, $SD = 4.43$), and face-to-face ($M = 9.89$, $SD = 5.27$) conditions, F(2,46) = 2.24, $p = 0.12$.

Three one-way ANOVAs revealed that there were no significant differences in the babies' change scores for heart rate, respiration rate, and skin conductance (Table 2) across the three conditions. This pattern of results was consistent with prior findings.

Table 2
Tests of change score differences in physiological reactivity, by condition

	Video Chat	Video	Face-to-Face	Test Statistic
	M SD	M SD	M SD	
Heart Rate	−1.83 7.92	−4.55 7.22	−3.74 7.85	F (2,41) = 0.47, η^2 = 0.02
Respiration Rate	−0.37 2.33	−0.03 4.61	1.31 3.26	F (2,41) = 0.98, η^2 = 0.05
Skin Conductance[1]	0.06 1.35	0.66 1.16	0.68 0.45	F (2,33) = 1.38, η^2 = 0.08

$^{+}$ marginal; *$p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

[a] Note that the statistical power was reduced, because of a smaller sample size (n = 36) due to equipment malfunction, for the test of group differences in skin conductance change scores.

Hypothesis 2: Latency to Smile

The second hypothesis was that infants would smile earlier during the face-to-face interaction with their mothers than in the two screen conditions (Gusella, *et al.*, 1988; Hains & Muir, 1996, experiment 2). An ANOVA revealed a trend difference in the latency to smile (in seconds) between the video chat (M = 12.78, SD = 7.53), video (M = 8.40, SD = 3.06), and face-to-face (M = 6.97, SD = 8.00) conditions, F (2,43) = 3.10, p = 0.06, η^2 = 0.13, and planned post-hoc tests were used to examine whether the effect was in the predicted direction. Post-hoc Bonferroni-corrected tests revealed that the babies in the video chat condition took marginally longer to smile than babies in the face-to-face group (p = 0.06), but that there was no difference in the latency to smile between the babies in the video condition and either the video chat (p = 0.25) or face-to-face (p = 1.00) conditions.

An exploratory post-hoc analysis revealed that there was a difference between conditions in the latency for mothers to first hide in peek-a-boo, F(2,46) = 7.84, $p < 0.01$. The mothers in the video chat condition took the longest (M = 9.07 seconds, SD = 4.50), followed by mothers in the video condition (M = 5.06, SD = 3.24), followed by mothers in the face-to-face condition (M = 4.17, SD = 3.37). However this difference in the mothers' "latency to hide" was unrelated to the results for the babies' latency to smile (r = 0.16, p = 0.29). Latency to hide was also unrelated to the baby's attention (r = −0.07, p = 0.63), the mother's sensitivity (r = 0.22, p = 0.12), and the baby's smile frequency (r = −0.27, p = 0.07).

Hypothesis 3: Maternal Sensitivity

The third hypothesis was that the mother's sensitive behavioral style with the infant would be a significant predictor of the baby's emotional reactivity, as reflected in the number of baby smiles and in physiological activity.

To test this hypothesis, hierarchical linear regressions were performed using frequency of smiles, latency to smile, and each of the three physiological measures as dependent variables. In each analysis, experimental condition was entered for Step 1 using two dummy variables, and maternal sensitivity was entered in Step 2. Initial analyses also examined the effect of the interaction terms between experimental condition and maternal sensitivity, but this additional step did not result in significant increases in the proportion of explained variance for the models (all $\Delta R^2 < .02$, *ns*) so was not included in the final model.

The regression using frequency of smiles was significant, $F(3,42) = 4.94$, $p = 0.01$, with an R^2 of 0.21, and revealed a statistically significant relationship between maternal sensitivity and the frequency of infant smiles, $B = 2.40$, $SE\ B = 0.68$, $\beta = 0.47$, $t = 3.52$, $p < 0.01$, such that each additional point of rated sensitivity predicted an additional two smiles from the baby during the interaction period. It failed to reveal a relationship between the frequency of smiles and experimental condition.

The addition of Step 2 (maternal sensitivity) to the regression using latency to smile did not result in significant increases in the proportion of explained variance for the model. Step 1 of the model, with an R^2 of 0.13, was statistically identical to the one-way ANOVA testing Hypothesis 2 (see above). None of the steps resulted in significant changes in R^2 for the physiological measures of heart rate, respiration rate, or skin conductance.

We conducted a second hierarchical regression to examine whether the group difference in the mothers' latency to hide was related to the babies' smile *frequency*. The mother's latency to hide was added in Step 1, and experimental condition was added in Step 2. While Step 1 (mother's latency to hide) did not add a significant amount to R^2, Step 2 (condition) did ($\Delta R^2 = 0.14$, $p = 0.04$). The full regression model was significant, $F(3, 42) = 3.19$, $p = 0.03$, $R^2 = 0.19$, and revealed a significant difference in smile frequency by condition, which was not evident before: Children in the face-to-face condition smiled more than those in the video chat condition ($p < 0.01$), and those in the video condition also smiled more than those in the video chat condition ($p = 0.01$). There was no difference between video and face-to-face. The mother's latency to hide was also a significant predictor ($p = 0.01$) when entered into the model with condition as another predictor (i.e., Step 2), such that each additional second that it took the mother to begin playing peek-a-boo predicted about 1 *additional* smile from the baby on average (see Table 3). When this positive influence on baby smiles was accounted for in the model, babies in the video chat condition smiled less often than those in the other conditions.

Table 3
Latency to Hide and Condition as Predictors of Smile Frequency

	B	SE	ß
Constant	4.45**	1.63	
Mom's Latency to Hide	0.62**	0.23	0.45**
Video Chat Condition	−5.51*	2.24	−0.45*
Video Condition	−0.21	1.89	−0.02
R^2	0.19		
F	3.19*		

$^{+}$ marginal; *$p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Discussion

Today many families are using video chat with their babies in an attempt to develop and maintain relationships between their babies and a remote relative (McClure & Barr, 2017). While families are capable of supporting such calls fairly successfully at home, at least among infants up to 24 months of age and with remote grandparents (McClure & Barr, 2017; McClure *et al.*, 2017), it has remained unclear whether babies emotionally engage in these calls with their loved ones in a way that resembles face-to-face interaction. To our knowledge, this is the first study to address this question systematically in a single experiment. It is also the first to employ physiological methods in the examination.

As expected 6- to 12-month-old infants were engaged during peek-a-boo as indexed by eye contact and smiling, but we did not observe infants in this age range imitating the peek-a-boo behavioral response by attempting to cover their own faces. Initial tests of the physiology measures demonstrated that the peek-a-boo interaction was an effective manipulation of the babies' emotional and attentional behaviors and physiological activity across the three conditions. Specifically, babies' heart rates decreased and their skin conductance levels increased between baseline and the interaction periods. In other words, the babies appear to have found the interaction period engaging, regardless of their experimental condition.

This study was conducted with three hypotheses in mind. The first hypothesis test yielded results that are consistent with Hains and Muir's (1996, experiment 1) study with mothers: Babies paid the same amount of attention and smiled just as often when their mothers played peek-a-boo with them face-to-face, via video chat, and via non-contingent video. These equal levels of emotional reactivity were also reflected in similar patterns of physiological activity across the conditions. Hains and Muir (1996) argued that babies may be tolerant of short periods of minor non-contingency from their mothers, given their familiarity with their mothers' interaction style, which would explain the lack

of difference between the video condition and the two contingent conditions. This is consistent with naturalistic observations of babies' and toddlers' attention levels during video chat interactions at home, which were unaffected by technical problems that decreased the contingency of the interaction (McClure & Barr, 2017).

The second hypothesis was partially confirmed: Babies took *marginally* longer to smile when using video chat than when interacting face-to-face; this difference was statistically significant only when maternal sensitivity was also included in the test. Furthermore, the video condition unexpectedly fell between the video chat and face-to-face conditions on this dimension, differing from neither of them. The speculative, post-hoc hypothesis that the mother's latency to hide for the first time may have affected the babies' latency to smile across the conditions was tested. Mothers in the video chat condition took significantly longer to hide the first time than those in the other two conditions, but this was unrelated to the babies' latency to smile, and so does not explain the unexpected result. This exploratory analysis did reveal, however, a result relevant to Hypothesis 1: Mothers' latency to hide was positively related to the frequency of baby smiles, and when this factor was held constant the babies in the video chat condition (where the mothers' latency to hide was the longest) smiled fewer times than those in the other conditions. Future studies should examine experimentally whether mothers in video chat conditions are successfully buffering the lower number of smiles by engaging with the baby for longer prior to beginning the formal interaction.

The third hypothesis was confirmed: Maternal global sensitivity did indeed play a significant role in predicting infant smiles (but not latency to smile), and did so over and above experimental condition. In other words, global maternal sensitivity is more important for eliciting positive responses from babies than the medium by which they interact. This suggests that mothers can use the same repertoire of engaging interaction techniques they might use in typical face-to-face interactions to successfully interact with their babies by video chat. This is significant, given that some parents rely on video chat interaction with their children when separated from them by work, deployment, incarceration, or travel (Yarosh & Abowd, 2011, Yarosh, Chieh, & Abowd, 2009).

Further analyses revealed that when mothers spend additional time engaging their babies before launching into more formal play activities, they receive a more positive response from their babies. More research is needed on the relation between this behavior and the babies' responses; however, if this strategy is shown to be successful in systematically increasing babies' positive responses to video chat, this behavior could be used as a guideline for parents who are hesitant or unsure of how to interact successfully with their young children via video chat. Future research should identify other successful behaviors that parents can use to engage their babies during video interactions, with the ultimate goal of educating parents – or even "training" at-risk parents in intervention settings – on how to interact successfully with their children remotely.

There is some evidence here and in Gusella, *et al.* (1998) that babies are sensitive to the difference between their mothers on screen and face-to-face, as evidenced by a longer hesitation before their first smile. Given this possibility, it is important that one not mistakenly conclude that video chat is "just as good" as face-to-face interaction for babies. While video chat may provide a promising mode of remote communication for babies and their remote relatives, it is not the same as traditional interaction. To put it colloquially: Video chat may be better than *nothing* (i.e., no interaction with the absent parent), but it is not as good as the real thing.

This is especially important to consider under circumstances in which video chat is used to replace face-to-face contact. For example, according to a new report by the Prison Policy Initiative (Rabuy & Wagner, 2015), many jails (but rarely state prisons) have begun implementing programs incorporating video chat visitation between inmates and their families. In a survey of these jails, they found that 74 % of them subsequently banned in-person visitation after implementing the video chat visitation programs. In fact, one of the two main companies supplying video chat services to jails and prisons includes this requirement in their contract – i.e., that in-person visitation must be banned following implementation of their for-profit video services. Researchers at the University of Wisconsin are currently testing whether providing families with tablets and coaching for parents might enhance video chat visits between children and their parents who are in jail (Western, 2019). Further research examining both the short- and long-term impact of exclusive video chat interaction between infants, children, and parents is urgently needed.

Limitations and Future Directions

This study had a number of important limitations. First, there were occasional lags between the mother's video and audio input in the screen conditions, and mothers sometimes unintentionally disappeared from view. Statistical analyses revealed that the frequency of these delays did not affect the measured outcomes. Relatives are frequently and unintentionally obscured from view when using video chat, and delays due to internet disruption occur frequently during naturally occurring video chat interactions (McClure & Barr, 2017), so it can be argued that the present study has ecological validity. These errors however, do limit the interpretation of this otherwise well-controlled experimental study, dampening the degree to which differences due to condition alone are being measured. Future studies should incorporate methods to control for these types of errors.

Second, in other ways ecological validity was diminished when achieving experimental control between conditions. Unlike video and video chat conditions, where a lack of physical contact is a defining feature, when mothers and their babies have ordinary, face-to-face interactions they make frequent physical

contact (Ferber, Feldman, & Makhoul, 2008). In the current experiment, however, the face-to-face interaction occurred at a distance (from the mother's booth) and infants did not have physical contact with their mothers. This set-up may have artificially reduced the number of smiles in the face-to-face interaction. Future studies should include less constrained face-to-face peek-a-boo interactions as well, to provide typical estimates of rates of smiling in dyad during face-to-face interactions.

Third, due to a skin conductance sensor malfunction and an amplifier calibration error during data collection, there were higher rates of data loss, limiting the interpretation of this measure. Furthermore, the collection of both skin conductance and respiration rate data proved challenging with such young subjects, which led to high levels of movement artifacts that needed to be removed. Replication of these measures in future studies is needed before firm conclusions can be drawn.

Finally, the present study focused on a single observation of mother-infant interactions where the infant has a long history of face-to-face interactions. Often video chat is used as a means to maintain contact with remote family members who are away for extended periods due to military deployment, divorce, incarceration, or simply living in distant locations, particularly grandparents who are geographically separated (McClure & Barr, 2017). There are, to our knowledge, no longitudinal studies following the impact of consistent, naturalistic video chatting between infants and any family member maintaining long-term contact from a distance. However observations of single naturalistic interactions of this kind (McClure & Barr, 2017, McClure *et al.*, 2018) suggest that video chat contact can be very positive for both infants and relatives, and that parents, relatives, and infants respond and adapt well to imperfect conditions for video chat interactions. Additional longitudinal research is needed to examine how interactions develop over the course of time as a function of the frequency (or lack thereof) of face-to-face interactions to examine ways to maintain and support relationships during early childhood. The present study suggests that positive interactions via video chat can occur and that patterns of physiological responding do not differ between video chat and face-to-face conditions, at least when infants are interacting with their mothers, but additional research is needed to confirm these results and to examine infants' responses within other relationships, as well as across time.

Conclusion

This experimental study was the first to systematically compare infants' emotional responsiveness to their mothers across face-to-face, video chat, and non-contingent video. Prior to this study, it was unclear how sensitive, face-to-face mother-infant interactions would be affected by screen mediation.

The results reveal that the game of peek-a-boo is equally exciting for babies when their mothers play it with them, regardless of the medium chosen. Furthermore, the babies' positive responses were more dependent on their mothers' global sensitivity than on the mode of interaction. This suggests good news for mothers who rely on video chat to interact with their babies when they are separated from them: it appears that mothers can use their usual repertoire of sensitive interactions and games to elicit positive responses from their babies, even via video chat and pre-recorded video. It also provides support for the use of programs like *United through Reading*, (Yeary, *et al.*, 2012), a program that allows deployed parents to create video recordings of themselves reading a children's book aloud to their child at home. This study demonstrates only short-term tolerance of non-contingency in screen presentations, though, so research on use of video chat for geographically separated parents and infants is needed. The results also demonstrate that babies are sensitive to differences between video chat and face-to-face interactions on at least one dimension. (i.e., latency to smile), even in the unnatural face-to-face scenario produced in the lab, so caution should be used when considering the sole use of video chat for parent-infant interactions.

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