A sense of privacy[1]

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Abstract

Among the many factors that can elicit privacy concerns and affect privacy behavior, some are sensorial: detecting the presence of others through our senses. Human beings may be wired to react to sensorial cues and rely, in part, on them to assess the privacy ramifications of their actions. Individuals may react to sensorial cues indicating the presence of others even when those cues do not carry relevant information about likely consequences of privacy choices – and thus, from a normative perspective, may not be expected to influence privacy concerns and resulting behaviors. In four experiments (N = 829), we examine the effect on privacy-relevant behavior (the disclosure of sensitive personal information) of four sensorial cues signaling the presence of other humans: proximity, visual, auditory, and olfactory, each signaling the presence of another person. Proximity and visual cues (Experiments 1 and 2) produced an inhibitory effect on intimate self-disclosures in an online survey – including when that presence does not and cannot materially affect participants' risks or benefits associated with disclosure (Experiment 2). Auditory and olfactory cues (Experiments 3 and 4), however, did not. The findings point to a possible influence of sensorial (specifically, visual) cues on privacy behavior. We discuss the implications of the findings in the context of privacy and security decision making in a digital age, where physical cues human beings may have adapted to use for detection of threats may be absent, or even strategically manipulated by antagonistic third parties.

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Introduction

Humans are social animals. In the physical world, we manage privacy intuitively, regulating openness and closeness towards others based on cues in our environment (Altman, 1975). We navigate the boundaries of public and private (Petronio, 1991), reacting naturally to changes in context (Nissenbaum, 2011). In digital realms, contexts more frequently collapse (Marwick and Boyd, 2011; Vitak, 2012), and privacy management can become more daunting (Wang et al., 2011): we carefully avoid any mention of our Saturday night escapades to the boss as we meet them in the office, yet post revealing pictures of that night on social media, forgetting they can see our profile. Online, it seems, we often become comfortable with privacy-sensitive behaviors we would hardly consider engaging in offline: we reveal a sensitive bit of information to a friend on a messaging app, even though its content is fully monitored and recorded by the service provider, but we lower the tone of a delicate dinner conversation as soon as the waiter approaches.

The factors that can differentially affect offline and online privacy stances are many and diverse. Some are obvious: risks and benefits associated with our actions are materially different in physical compared to digital realms. The waiter at the restaurant may recognize us; to the messaging service provider we are a faceless user among millions. A stranger closely following us in an isolated street at night raises a threat of physical harm much more immediate and ominous than a data mining company closely surveilling all of our online clicks. Objective differences in risk and harm, however, are not the only dimensions factoring in the diversity of privacy responses online and offline. Culture, social norms, or habits are others. And yet another is the different degree of information asymmetry – online relative to offline – regarding the consequences of our privacy choices. Online, asymmetric information is endemic (Acquisti, Brandimarte, and Loewenstein, 2015): individuals often lack knowledge of when their information is collected, how it is used, and with what consequences. The ramifications of sharing Saturday night stories face-to-face with a boss at the office are vivid and present in our minds – less so on Facebook, where we may not realize the breadth of the potential audience of our posts (Bernstein et al, 2013).

We argue that a peculiar and fundamental source of information asymmetry in digital contexts is the lack of sensorial cues indicating the physical presence of others. Lack of those cues inhibits our ability to detect others encroaching into our virtual spaces. Online, we do not *see* Google leaning over our shoulders to track our sensitive searches; we do not *hear* the NSA stepping closer to listen to our Skype conversations; we do not pick up the *scent* of Facebook following us across all the locations where we carry a smartphone. And yet, human beings may be wired to rely in part on those very sensorial cues to assess the privacy implications of their behaviors. This discrepancy may create a deficit in our ability to manage privacy sensitive scenarios in digital realms, relative to the physical world.

In four lab experiments (N = 829), we study whether the presence or absence of sensorial cues indicating the physical proximity of another person through one or more of the senses (physical proximity, sight, hearing, smell) can affect privacy behavior, even when those cues may not actually provide relevant information for the individual's privacy calculus (i.e., their rational cost-benefit analysis of the consequences of that behavior, Laufer and Wolfe, 1977). We focus on informational privacy and operationalize privacy-relevant behaviors as willingness to engage in intimate self-disclosures (Moon, 2000) in an online survey. Across the experiments, we find that proximity and visual cues (Experiments 1 and 2) produced inhibitory effects on intimate self-disclosures in an online survey, whereas auditory and olfactory (Experiments 3 and 4) cues did not. Some inhibitory effects are found also when the presence of other individuals does not affect participants' actual privacy risks and trade-offs (Experiment 2). The findings point to a process through which sensorial (specifically, visual) cues can affect privacy choices: a "sense" of privacy.

Cues in our environment guide our behavior, but can be misread or misused. This happens offline as much as online. Offline, people can miss the cues of pervasive and permanent camera surveillance (Oulasvirta et al, 2012) while paying unnecessary attention to irrelevant behaviors by others (Prechter, 2001). Online, individuals can ignore crucial warnings (Egelman, Cranor, and Hong, 2008) but react to irrelevant cues in interfaces, such as the look-and-feel of a website (John, Acquisti, and Loewenstein, 2011). Yet, the implications of an influence of sensorial cues on privacy behavior seem particularly far-reaching in the online world. The unforeseen ramifications of our online disclosures can be both positive and negative. When negative, they can go well beyond mere embarrassment, from a job opportunity lost (Acquisti and Fong, 2020) to a data miner's ability to micro-target large groups of voters to influence their country's elections (Aral and Eckles, 2019). If people do rely, in part, on sensorial cues to navigate privacy choices, then the more we transition from physical and spatial privacy (Warren and Brandeis, 1890) to informational privacy (Westin, 1967), the less equipped we may be for informed digital privacy decisions. At the extreme, in cyberspace, sensorial cues may be absent, subdued, or even intentionally manipulated by third parties (Conti and Sobiesk, 2010). Thus, privacy (and security) response mechanisms common in the offline world may not be activated online, where personal information, once disclosed, can be so easily and widely distributed and exploited, and nearly impossible to remove. This may explain a number of surprising and even paradoxical findings uncovered in the privacy literature, as well as the hurdles we face in protecting online privacy (see Discussion).

Experimental Design

Four lab experiments investigate the effect of sensorial cues, indicating the presence or absence of human beings, on privacy-relevant behavior. Building upon Moon (2000)'s work on intimate self-disclosures, we operationalize privacy-relevant behavior as disclosure of personal, sensitive information via open-ended answers to an online survey (Table A1 in the Supplementary

Materials).[3] Each experiment focuses on a different sensorial cue: proximity (Experiment 1), visual (Experiment 2), auditory (Experiment 3), and olfactory (Experiment 4). Each experiment consists of two conditions: a treatment and a control condition. In the treatment condition, the sensorial cue elicits a sense of the physical presence of a human being; in the control condition, the sensorial cue is designed to elicit the detection of an inanimate object via the same sense.

Self-disclosure refers to the revelation of personal information to others (Archer, 1980). Intimate self-disclosures are those containing high-risk information that may make the discloser feel or be vulnerable in some way (see Moon, 2001; Derlega et al., 1993; on intimate self-disclosure in surveys, see also Tourangeau and Yan, 2007). Privacy concerns are concerns associated with the boundaries of a person's private sphere; in this context, these involve concerns associated with sharing intimate disclosures with others through a survey. The link between privacy concerns and willingness to self-disclose – in particular, intimate and sensitive information – has been frequently explored in both the theoretical (e.g., Derlega and Chaikin, 1977) and empirical literature (e.g., Andrade, Kaltcheva, and Weitz, 2002; Joinson et al, 2008; Joinson et al, 2010).

Sensorial cues can cause arousal and influence individuals' tasks in complex manners (Hockey, 1970; Benignus, Otto, and. Knelson, 1975; Olmedo and Kirk, 1977). We hypothesize that cues indicating the presence of individuals who are unknown to the subject, timed to coincide with a task that involves potentially privacy-sensitive choices, may heighten privacy concerns and elicit an inhibitory reaction, lowering willingness to disclose sensitive personal information during the survey itself. Changes in concerns are only measurable by proxy (self-reported measures of concern), but changes in behavior (differential willingness to disclose) can be captured directly and analyzed using metrics from prior literature. Following the literature on intimate self-disclosures and the literature on self-disclosure and privacy concerns (Collins and Miller, 1994; Moon, 2000; Joinson, 2001; Joinson et al, 2008), we focus on "depth" (the intimacy of disclosures, rated on a scale from 0 [Non response] to 4 [Very intimate]; see Table A2 in the Supplementary Materials) and "breadth" (word count) of the disclosure. In the survey, we include both sensitive and non-sensitive questions. As we expect human sensorial cues to specifically inhibit disclosure of intimate information, we focus on the differential effect of treatment on sensitive, relative to non-sensitive, questions (John et al., 2011).

All experiments are designed around the addition of sensorial cues to a physical environment in which the subject is carrying out private online activities. Experiment 1 uses a forceful manipulation of proximity, which is comprised of visual, auditory, and olfactory cues. This manipulation does not merely suggest the presence of other human beings, but in fact exposes the participant to potential privacy risks; thus, Experiment 1 tests for reactions to material changes in trade-offs associated with participants' disclosures. Experiments 2-4 selectively employ cues that do not directly affect privacy risks, and thus should not be expected to affect participants' calculus

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[3] All Supplementary Materials are available from the authors on request.

of trade-offs associated with disclosure. Across treatment and control conditions within each experiment we hold constant other factors that may differentially influence privacy decision making online and offline (such as trust, nature of trade-offs associated with different choices, cultural factors, and so forth). Thus, the design isolates the effect of specific sensorial cues from the effect of calculus-based considerations on privacy decision making.

Participants were recruited from a demographically diverse (in terms of gender, race, age, and employment or educational status) North-American University's experimental participants list for a study on emotions. Upon arrival at the lab, each participant was shown to a specially prepared room, separated by a door and a large glass window from an adjacent, empty room. The participant sat in front of a laptop, facing the window. First, s/he was prompted by the computer screen to answer a series of questions regarding the environment around her/him and the emotions it aroused. These questions were designed to make participants aware of their surroundings. Next, the participant completed a set of open-ended personal questions (originally used by Moon, 2000). They included a non-randomized, non-sensitive opening question (henceforth, "OQ"), followed by a set of five focal questions ("FQs"; Table A1) in randomized order. The focal questions were classified as either sensitive or non-sensitive based on ratings gathered in a separate pilot conducted before the experiment, and are the focus of the analysis.

The experimental manipulation consisted in the administering of sensorial cues timed to start at the moment the participant was presented with the OQ on the computer screen (henceforth, "trigger"). The trigger timing was identical across participants and across conditions. The manipulation cues therefore started being administered before participants were presented with the five FQs, to control for potential effects of distraction or surprise at the first appearance of a cue. Across all studies and conditions, the sensorial cues were designed to stop after four minutes independently of how quickly the subject was proceeding through the study (timing was set based on results from a separate pilot). Following the FQs, the participant was presented with a series of questions about emotions experienced in that moment (such as stress, happiness, and frustration), demographic questions, and manipulation check questions. Finally, exit questions captured participants' (self-reported, thus conscious) privacy concerns (based on Brandimarte et al., 2013): 1) whether they felt monitored during the study, 2) whether they were concerned about their privacy while answering personal questions, 3) whether they were worried that their responses could be linked to their identity, and 4) whether they felt uncomfortable while answering personal questions.

In the rest of the manuscript, we discuss the empirical strategy and the results for the four experiments. Additional details for the experimental procedure, for the analytical model, and for empirical analysis (including robustness tests and alternative specifications), as well as information on related work, can be found in the Supplementary Materials.

Empirical Strategy

We use a panel random effects specification to estimate the impact of the treatment on response depth (intimacy of disclosures) and breadth (word count) while controlling for individual factors. For each experiment, we estimate the following model:

$$y_{ij} = \beta_0 + \beta_1\, Treatment_i + \beta_2\, Sensitive_j + \beta_3\, Treatment_i \times Sensitive_j + \varepsilon_{ij} \qquad (1)$$

where y_{ij} is either the intimacy or the word count of the open-ended answer by participant i to question j, *Treatment* is a binary variable capturing the experimental condition, equal to 1 if the treatment consisted of a sensorial cue associated with the presence of a human being, and *Sensitive* is a binary variable equal to 1 if the question was rated sensitive in the pilot study. In model (1), the interaction between treatment and sensitivity of the question is the focus of the research hypothesis. β_3 indicates whether the detection presence of another person, indicated by a sensorial cue, has a differential effect on answers to sensitive relative to non-sensitive questions. We refer to this differential effect as the treatment effect of interest. Ordered logit regression is used for intimacy of responses and Poisson for word count. Standard errors are clustered at the individual level. (In the Supplementary Materials, we present results for the following additional specifications: controlling for demographics; using linear regression models; and testing the impact of the treatment on alternative DVs from the communication literature.)

Experiment 1 – Proximity Cue

In the control condition, the subject was alone in the room for the whole duration of the study. In the treatment condition, a male, Caucasian confederate entered the room following the trigger. The confederate wore security personnel clothes, moved around the room, stood behind the participant close enough to be able to read their screen, and pretended to check something under the table and in a corner of the room. For all this time, the confederate remained silent and was instructed not to interact with participants or get close to them. After four minutes, the confederate left the room. The confederate's proximity to the participant provided visual, auditory, and olfactory sensorial cues.

The design builds upon Couper, Singer and Tourangeau (2003)'s clever experiment, in which a confederate entered the room where the subject was working, pretending to be a computer technician needing to look at the screen of the computer in use by the subject, and interacting with her/him (in contrast, in our experiment the confederate did not directly interact with, look at, or talk with the subject). Couper et al. (2003) were interested in testing the effect of the medium used to deliver the questionnaire on social desirability bias, and did not find significant results; we focus on depth and breadth of intimate disclosure as a function of detection of a human being in the physical surroundings. In a seminal work, Joinson (2001) observed higher levels of spontaneous self-disclosure in dyads of individuals discussing a dilemma using a computer-mediated communication system relative to dyads discussing face-to-face. The focus of our design was not on the effect of the medium (computer-mediated vs. face-to-face communication) in synchronous communications between individuals, but rather on the effect of the presence or absence of sensorial cues on self-disclosure in an online survey.

Results

Two-hundred-fifteen participants (55% female; 42% Caucasian; $M_{age} = 24.82$, SD = 8.54) took part in Experiment 1. For this and all other experiments, Table A3 in the Supplementary Materials presents summary statistics for both dependent variables.

Table 1 presents the results for regression (1). Recall that we defined above the treatment effect of interest as the differential effect of treatment, relative to control, for sensitive questions relative to non-sensitive. The treatment effect of interest for intimacy of responses is negative but not significant ($\beta_3 = -.49$, $p > .1$). For word count, the estimate for β_3 is negative and significant ($\beta_3 = -0.46$, $p < .01$), indicating a reduction in the number of words used in open-ended responses to sensitive questions, relative to non-sensitive, in the treatment condition (in the Poisson specification, the decrease is captured in log counts).

Looking at the average intimacy of responses to sensitive vs. non-sensitive questions in the control and in the treatment conditions with 2-sided paired t-tests (Table A3) provides insights into the interactions from the regression results. Not surprisingly, participants produced fewer words in response to the sensitive questions than non-sensitive ones in both the treatment and control conditions, although this effect is larger in the treatment condition (d = 0.64, $p < .01$). The Intimacy of the answers, however, is significantly lower for sensitive versus non-sensitive questions when the guard is present ($p < .05$; effect size: d = .32) but not different in the control. It appears that the sensitivity of questions alone does not affect participants' willingness to disclose: it is only when that sensitivity is made salient by the proximity of a stranger that participants disclose less.
A repeated-measures ANOVA of the four measures of privacy concern captured in the exit survey shows a significant effect of the treatment ($F(1, 212) = 9.22$, $p < .01$), indicating that participants report higher privacy concerns in the treatment (M = 3.88, SD = 1.57) than in the control condition (M = 3.21, SD = 1.63). Mediation analysis (presented in the Supplementary Materials) suggests a causal link between heightened privacy concerns and diminished willingness to disclose (Sobel test: z = 2.40, $p < .05$).

In summary, when the guard was present, participants produced disclosures to the sensitive questions that contained less breadth than when the guard was absent relative to disclosures to the non-sensitive questions. Intimacy of disclosure was lower for sensitive relative to non-sensitive questions only when the guard was present; however, the interaction between treatment and sensitivity was not significant.

Control and treatment conditions in Experiment 1 capture antithetical contexts: the absence vs. the physical presence of a stranger close to the subject while s/he is responding to sensitive questions in an online survey. Thus, the experimental design tests whether close proximity of a human being during a privacy-sensitive task reduces intimate online self-disclosures, but does not establish whether participants responded to the sensing of another person in their proximity and, if so, which type of cue triggered the inhibition, or to the potential risk of a person reading their answers and later identifying them. Experiment 2 isolates visual cues and tests whether they can affect privacy-related behaviors even when they do not materially affect participants' actual benefits or risks from disclosure. Experiments 3 and 4 isolate and test whether increasingly subtler sensorial cues can similarly affect privacy-related behavior.

Experiment 2 – Visual Cue

In the control condition, the visual cue consisted of a fan located behind a window in the adjacent room, in full view of the participant. The quiet fan was remotely activated by the experimenter following the trigger. Once activated, the fan oscillated along its horizontal axis. In the treatment condition, a male Caucasian confederate, acting as a window repairman, entered the adjacent room following the trigger, and faced the subject through a glass window in the same position as the fan in the control condition. The confederate did not make eye contact with the participant and remained silent for the entire time he remained in the adjacent room, only checking the window. The participant could see and be seen by the confederate, but could not hear or smell him, or enter in physical contact with him. The confederate could not see the participant's screen, nor their answers to the survey questions.

In an astute study, Tourangeau, Couper, and Steiger (2003) show experimental participants the picture of either a male or a female co-author (or neither, in a control condition) at the top of a web survey. The authors' purpose was to measure the effect of "humanizing" a questionnaire on social desirability bias, impression management, and attitudes towards gender stereotypes (the latter dependent variable is the only one where a significant effect was found). The experimental design, purpose, and results (as discussed below) are different in Experiment 2. Rather than focusing on visual representations of other humans, the goal of Experiment 2 was to isolate the effect on self-disclosure of a visual cue signaling the physical presence of a human being (as compared to an inanimate object) in the proximity of the subject.

Results

Two-hundred-six participants (55% female; 40% Caucasian; $M_{age} = 25.31$, SD = 9.71) took part in Experiment 2. When the confederate was within the participant's visual field, though unable to see their survey answers, participants produced disclosures to the more sensitive questions that were both less intimate and shorter than when they saw a moving fan (Table 1). As in Experiment 1, Table A3 shows no significant difference in the intimacy of responses to sensitive versus non-sensitive questions in the control condition, but a reduction in intimacy of responses to sensitive (M = 1.03, SD = .73) versus non-sensitive questions (M = 1.17, SD = .48; $p = .05$; effect size: d = .22) in the treatment condition. The same pattern is observed for word count.

Self-reported privacy concerns were heightened by the visual presence of another human (M = 3.99, SD = 1.47) as compared to the fan (M = 3.50, SD = 1.51; $F(1, 204) = 5.46$, $p < .05$). Manipulation checks confirm that participants detected the presence of the guard or the fan in the other room. Mediation analysis suggests a possible causal link between self-reported privacy concerns and willingness to disclose, but the evidence is not conclusive (Sobel test z = 1.77, $p < .1$; see Supplementary Materials).

In summary, a person entering the visual field of the participant had an inhibitory effect on the intimacy and word count of open-ended answers to sensitive questions, and raised self-reported privacy concerns. This happened even though the confederate could not monitor participants' disclosures or interact with them. Experiments 3 and 4 isolate additional, more subtle sensorial cues presented in a manner in which there was no material risk to privacy behaviors.

Experiment 3 – Auditory Cue

In the treatment condition, the auditory cue consisted of idle chatter from another human being (a male confederate) talking in the adjacent room. The chatter came from an audio file reproducing bits of conversation that a confederate had pre-recorded following a script simulating a phone conversation. The bits of the conversation were randomly arranged into different audio sequences, randomly played to treated participants. The audio file was played using speakers hidden in the adjacent room at a constant volume, pre-tested so that a participant could hear it in the other room. Thus, while participants could not see any human beings around them during the study, they could hear the sound of a male voice. In the control condition, the audio file consisted of a fax-machine sound played at the same volume as the simulated phone call. In both conditions, the audio playbacks started at the trigger.

Berg et al. (2017) captured the effect of multiple unexpected audio stimuli on a security-critical task. They did not focus on the differential effect on disclosure of auditory stimuli associated with humans to those associated with an inanimate object.

Results

Two-hundred-six participants (53% female; 43% Caucasian; $M_{age} = 25.37$, SD = 9.57) took part in Experiment 3. Model (1) indicates that the treatment effect of interest for both intimacy and word count was not significant (Table 1). Thus, the auditory detection of another human did not have the same inhibitory effect as proximity or visual cues.

Participants' explicit privacy concerns do not show a significant effect of the treatment ($F(1, 204) = .84$, $p > .10$), suggesting that the auditory cue did not raise conscious privacy concerns relative to control.

Experiment 4 – Olfactory Cue

The olfactory cue consisted of the participant being asked to open a vial following the trigger and smell its solution. In the treatment condition, the solution contained a synthetic human chemosignal (specifically, a male human biological steroid called androstadienone). Chemosignals affect physiological and psychological states, such as attention, sexual arousal, and ovulation timing (Jacob et al., 2001; Stern and McClintock, 1998), as well as actual behaviors (Beauchamp et al., 1976). This occurs even unconsciously, when the relevant chemosignal is not recognized. We conjectured that even unconscious detection of a human chemosignal may affect participants' privacy perceptions, and therefore affect their willingness to disclose intimate information. Certain odors are associated with the presence of other human beings, and precise methods to liberate them in a physical space have been used in lab experiments to elicit emotions or unconscious reactions in other humans (Jacob et al., 2001; Zhou and Chen, 2009). Following Jacob et al. (2001) we dissolved androstadienone (99% purity) in clove oil (1% clove oil in 250 µl propylene glycol) at an undetectable concentration of 250 µM presenting 9 nmol.[4] In the control condition, the vials contained only clove oil.

Results

Two-hundred-two participants (52% female; 41% Caucasian; $M_{age} = 22.87$, SD = 6.91) took part in Experiment 4. Model (1) indicates that the treatment effect of interest for both intimacy and word count was not significant across the entire sample (Table 1).

According to self-reports, the cue did not consciously raise higher privacy concerns among participants in the treatment condition (M = 3.47, SD = 1.50) relative to control (M = 3.39, SD = 1.32; $F(1, 204) = .16$, $p > .10$).

Discussion

Two experiments (Experiments 1 and 2), where either close proximity or mere visual cues alerted participants to the presence of another person, reduced willingness to disclose sensitive personal information in an online survey while increasing self-reported privacy concerns. The phenomenon occurred when the sensorial cue was designed so as not to increase objective risks that the information provided could be accessed, compromised, or abused (Experiment 2). In two experiments where the sensorial cues were not visual or not even consciously processed

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[4] At this concentration, androstadienone has effects on cortical processes and brain metabolism even though it is not detected consciously (Jacob et al., 2001).

(Experiments 3-4), we did not detect similar inhibitory effects. The findings reveal that the visual sense of another person triggered both privacy concerns and an inhibitory behavioral effect on disclosure, while hearing or smelling an individual did not.

The impact of cues related to the presence of other people has been examined in several related domains. The presence of "watching eyes" on signage, for example, can trigger a sense of being observed and increase pro-social behavior (e.g., increased charity, reduced bicycle theft) relative to when the watching eyes signage is not present (Nettle, Nott and Bateson, 2012). The presence of a person can also increase social desirability bias in survey responses relative to self-administered surveys. Surveys with a human interviewer present generally results in the under-reporting of stigmatizing behaviors, such as drug use (Newman et al., 2002; Groves et al., 2011). Here, we examine how sensorial cues that humans are physically present can influence privacy behaviors. Unlike prior work, our experiments were designed to tease apart 1) the influence of specific sensorial modalities (i.e., visual, auditory, olfactory) and 2) whether sensorial cues influence privacy behaviors even when such cues indicate no material risk to one's privacy (e.g., someone is nearby but cannot see one's behavior).

The power of the visual sensorial cue is consistent with other work indicating the dominance of the visual system for humans. Under many circumstances, humans rely more on visual information than other forms of sensory information, a phenomenon referred to as the Colavita effect (Sinnett, Spence and Soto-Faraco, 2007). The dominance of the visual system is not confined to humans, since a majority of biologically-relevant information is received visually (Partan and Marler, 1999). Furthermore, since the hearing and olfactory cues were irrelevant to the privacy behavior (i.e., their written disclosures could not be heard or smelled), those sensorial cues did not trigger privacy concerns nor changes in privacy behaviors. Under circumstances where those sensorial cues were relevant to the privacy behavior, such as hearing someone nearby while vocally sharing a secret, they may also trigger privacy concerns and behavior inhibition.

In nature, the ability to detect and react to threats in the physical environment is rewarded. Different species developed perceptual systems specially selected to assess sensorial cues for current and material risks. For humans, those systems may include the perception of the presence of others in one's proximal physical space, and the ability to rapidly differentiate between threats and non-threats – for instance, distinguishing strangers from friends and adapting behavior accordingly from protective to cooperative.[5] The evolutionary advantage of being able to process and react to sensorial cues originating from the presence of others is clear: by using those signals to assess threats in their physical proximity, humans reduce the chance of being endangered (Darwin, 1859). While it is not possible to test an evolutionary conjecture directly, some of our evidence - and in particular the reaction to visual cues - is compatible with an account of privacy concerns as byproducts of ancestral drives, consistent with Warren and Brandeis (1890)'s notion

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[5] On evolutionary perspectives about ingroup and outgroup differentiation, see Brewer (1999). See also footnote 4.

of privacy as the right to be left "alone." Under such an account, the need for privacy may have evolutionary roots (see Westin, 1967, p. 8; Klopfer and Rubenstein, 1977; Epstein, 1980; Hirshleifer, 1980; Moore, 2003).

What we refer to as modern privacy concerns may have in fact evolved from a need for security and self-interest. In our past, the ability to detect and appropriately react to the presence of others by selectively choosing exposure or protection, openness or withdrawal, would have been a source of advantage not only for short-term survival, but also the longer-term ability to engage in effective reputation and impression management (Schlenker, 1980; Buss, 1996). Barkow (1989), for example, suggested that the primary evolutionary function for the self could be impression management; selecting information about oneself to make favorable impressions on others (Schlenker, 1980) and using reticence and withdrawal to "reduce the risk of saying or doing something that others might regard negatively" (Baumeister and Leary, 1995, p. 520) as a method for such management. Sensorial cues may still influence today how we define boundaries between public and private, and how we instinctively perceive encroachments into the latter (for instance, the familiar feeling that alerts us when someone is observing us while we are lost in thought): a "sense" of privacy, so to say. Indeed, this account is consistent with research on objective self-awareness, in which situations that highlight that we are in public can lead us to behave more normatively (Duvall and Wiclund, 1972). Extending the work presented here to cross-cultural settings, exploring links between genetic data and privacy behaviors, and conducting fMRI studies may be ways to further investigate this account.

Such an account does not posit that hiding is more advantageous than sharing, or that being alone is safer than being with others. First, as implied above, the need for (and potential evolutionary explanation of) privacy is perfectly consistent with the need for socialization and sharing, as well as with the quest for rewards from disclosure (Tamir and Mitchell, 2012). Across its many definitions and dimensions (from spatial, to informational, to decisional: Solove, 2005) privacy is better understood not as a monolithic state of withdrawal and avoidance, but rather as a dynamic and dialectic process of interaction with others – a boundary control process whereby people "sometimes make themselves open and accessible to others and sometimes close themselves off from others" (Altman, 1977, p. 67). The risks of loneliness are well known (Reichmann, 1959), and so are the benefits of self-disclosures (Reis and Shaver, 1988; Pennebaker, 1997; Frattaroli, 2006). Evolutionary explanations relying on gossip, communication, and coordination (as well as deception) among early humans (Dunbar, 1996; Dunbar, 1996) have been proposed to explain why, among primates, we are the only species whose gaze can be detected (Kobayashi and Kohshima, 2001).[6] Second, the ability to detect others and modulate an appropriate response (such

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[6] Familiarity and kinship relationships may mediate disclosure reactions also in cyberspace (see Piazza and Bering, 2009). Future work may investigate visceral reactions to the detection of individuals who are in fact, rather than strangers, known to the subject.

as the degree of openness or exposure of the self to the other) is advantageous not just in terms of protection from risk, but also in terms of extraction of benefits.[7]

In fact, both dynamics can be readily observed among other species. Cats seek seclusion when ill (protection against risk dynamics);[8] chimps lower in the social hierarchy try to conceal their activities from higher-status males in the group when mating or after finding a coveted source of food (extraction of benefit dynamics).[9] Both dynamics are surprisingly consistent with modern *economic* accounts of informational privacy. People have a rational desire for privacy, intended not as mere blockage but rather as control over personal information (that is, the ability to decide what to share and what to protect), so as to guard or advance their well-being. An individual may naturally want to share with a marketer her interests and preferences, so as to get beneficial targeted offers (extraction of benefit dynamics); but may not want the marketer to know her willingness to pay for those interests, in order to avoid price discrimination (protection against risk dynamics; Varian, 1996).

Offline as online, the need for privacy may be interpreted as both an ancestral (and thus universal) want, and an ability for control of something personal – be that space, territory, body, or, more recently, information – over the encroachment by others that the individual does not deem advantageous. The ever-shifting boundaries between public and private are the contours along which every individual balances her need for exposure and sharing with her need for protection, her natural instinct to commune with others, and her awareness of the costs that may come with that communing. Ultimately, those are the shifting yet universal boundaries between our perceptions of self and of others.

Implications for Privacy in the Digital Age

Under the proposed account, modern informational privacy concerns may in part be byproducts of ancestral systems to assess threat based on sensorial cues. Today, those cues are attenuated, absent,

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[7] See Margulis (1977), where privacy is described as "selective control over transactions between self (or one's group) and others, the ultimate aim of which is to enhance autonomy and/or to minimise vulnerability" (p. 10).

[8] Hiding behavior is a stress-reducing strategy in cats (Kry and Casey, 2007).

[9] "In sum, there are innumerable instances of nonhuman animals acting in a manner that characterizes humans seeking privacy." (Klopfer and Rubenstein, 1977, p. 64). Two fascinating episodes involving chimpanzees engaging in "concealment" behavior are described in de Waal (2007): "Dandy [a young, lower ranking male chimpanzee in a chimpanzee enclosure] began to make advances to the female, while at the same time restlessly looking around to see if any of the other males were watching." When Luit, one of the older and higher-status males, unexpectedly came around the corner, "Dandy immediately dropped his hands over his penis concealing it from view" (p. 36-37 of the 25th anniversary edition). Separately, after researchers hid grapefruit in the chimpanzee enclosure as part of an experiment, Dandy was able to find the hidden spot. However, when "[a] number of apes passed the place where the grapefruits were hidden, [...] Dandy too had passed over the hiding place without stopping or slowing down at all and without showing any undue interest." The same afternoon he went back to the spot and "[w]ithout hesitation he dug up the grapefruits and devoured them at leisure. Had Dandy not kept the location of the place a secret, he would probably have lost the grapefruits to the others" (p. 62). Also, see Andelman (1987) on various hypotheses of evolutionary advantages of concealment behavior in animals (specifically, concealed ovulation in nonhuman primates).

or even intentionally manipulated by third parties' so-called dark patterns (Conti and Sobiesk 2010; Gray et al., 2018) in cyberspace. The gap between cues those perceptual systems may have developed to react to and cues available in cyberspace produces an evolutionary mismatch of sorts (Riggs 1993), and can provide insights over a series of puzzles that surround the contemporary study of privacy.

First, the account provides an additional explanation for why privacy reactions may differ online and offline in important ways, and why many may find it hard to manage online privacy. If privacy concerns have arisen as a byproduct of physical security concerns, then we may be ill-equipped to react to information privacy risks that happen online, where we lack the external cues we have adapted to rely upon for risk management[10] – a form of deficit between technological progress and our nature that may hamper privacy decision making in cyberspace.

Second, and relatedly, the account is compatible with the so-called privacy paradox (Norberg, Horne, and Horne, 2007) – the purported gap between privacy attitudes (or intentions) and privacy behaviors in digital domains. Privacy-negating online behaviors may not always arise from carelessness or lack of want for privacy. Instead, in absence of sensorial cues, elicited privacy concerns may not be sufficiently vivid in digital environments to affect behavior – even though digital behaviors are likely to leave identifiable and permanent rather than ephemeral traces (Hofstetter, Rüppell, and John, 2017). In fact, if subtle sensorial cues can alter privacy behavior in the absence of normatively relevant changes to privacy trade-offs, then modeling privacy decision making solely as the result of rational processes may not fully account for the malleable nature of privacy preferences. Taking these observations together, the account suggests that while people may in fact care for privacy (including online privacy), and may at times be able to act strategically about it, in digital realms they may also not always be in the best position to act on their concerns. This observation thus casts doubts over the reliance on self-regulatory policy regimes for privacy protection (often based on notice and control mechanisms, and individual responsibility; Solove, 2012), rather than regulatory interventions, which a number of governmental bodies across the world have been enacting or discussing.

Finally, the account is compatible with the observation that there exists an outstanding degree of heterogeneity and diversity in privacy mores and behaviors across individuals, geography, and time, but that there also exists surprising universality of privacy *needs* (Westin, 1967; Ariès and Duby, 1992; Murphy, 1964; Westin, 1984).[11] Sensorial cues are but one of many factors – among them culture, social norms, technological change, and so forth – which, collectively, influence privacy behavior. The complex way those factors interact renders privacy wants and behaviors mutable, heterogeneous, and context dependent. And yet, an ancestral root for privacy desires may

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[10] Note how, conversely, visceral surveillance primes such as depiction of eyes can affect behavior in both offline and online contexts (Nettle et al., 2013).

[11] Traits can be innate without being unchangeable: see Haidt (2005), and Marcus (2004), cited therein.

explain why references to privacy can be found across cultures distant in space and time, including the holy books of ancient monotheistic religions (Acquisti, Brandimarte, and Loewenstein, 2015). As Altman (1977) perceptively put it, over 40 years ago: privacy regulation may simultaneously be a culturally specific phenomenon and a culturally universal process.

Tables

Table 1. Regressions for Intimacy (Ordered Logit) and Word Count (Poisson), all Experiments, Model (1).

	Experiment 1		Experiment 2		Experiment 3		Experiment 4	
	Intimacy	Word count	Intimacy	Word count	Intimacy	Word count	Intimacy	Word count
Treatment	0.205	0.045	0.157	0.065	0.196	0.002	0.182	-0.202
	(0.156)	(0.143)	(0.173)	(0.138)	(0.154)	(0.154)	(0.159)	(0.137)
Sensitive	-0.292	-0.222*	-0.087	-0.163^{+}	-0.431^{+}	-0.630**	-0.837**	-0.487**
	(0.206)	(0.092)	(0.218)	(0.088)	(0.245)	(0.122)	(0.223)	(0.087)
Treatment*Sensitive	-0.494	-0.456**	-0.613*	-0.344**	-0.324	0.226	-0.253	0.089
	(0.314)	(0.155)	(0.308)	(0.129)	(0.316)	(0.167)	(0.308)	(0.128)
Constant	-	2.634**	-	2.600**	-	2.721**	-	2.839**
		(0.112)		(0.107)		(0.123)		(0.099)
N	1,075	1,075	1,030	1,030	1,028	1,030	1,010	1,010
Wald $\chi^2(3)$	13.67**	2156.92**	11.13*	1878.13**	18.53**	1895.14**	39.31**	2039.46**

$^{+}$ $p<0.1$; * $p<0.05$; ** $p<0.01$

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