IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received December 16, 2019, accepted January 10, 2020, date of publication January 27, 2020, date of current version February 4, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.2969562

Psychological Effects and Their Role in Online Privacy Interactions: A Review

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This work was supported in part by the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie Grant 675730.

ABSTRACT Because of the increasing dependency on online technologies in even the most ordinary activities, people have to make privacy decisions during everyday online interactions. Visual design often influences their choices. Hence, it is in the hands of choice architects and designers to guide users towards specific decision outcomes. This ''nudging'' has gained much interest among scholars in interdisciplinary research, resulting in experimental studies with visual cues that may have the potential to alter attitudes and behaviors. Attitude and behavior changes are often attributed to several psychological effects manifesting in cognitive processing and decision-making. This article presents the results of a systematic literature review carried out to identify which psychological effects have been previously studied in the context of online privacy interactions. Subsequently, fifteen articles were selected and thoroughly reviewed, resulting in the identification of twenty psychological effects. The visual cues triggering these effects were recognized and classified against their capabilities to alter privacy attitudes and behaviors. Specifically, the visual cues were divided into two categories: privacy-enhancing and privacy-deteriorating. This review discusses the applicability of such cues in research and UI design. Further, the findings are discussed against the existing research on digital nudges. The authors conclude with a discussion on issues of research quality in the privacy-related field and outline the road to improvement.

INDEX TERMS HCI, privacy, decision-making, attitude, behavior, visual cues, design.

I. INTRODUCTION

The user interfaces (UIs) of modern technologies, from the web to mobile-based services, implement various designs to enhance digital interactions. Frequently, these UI designs aim to guide users towards specific actions.

One of the theoretical approaches used in the design of such choice architectures is a concept from the findings of behavioral science and economics: *libertarian paternalism*. *Libertarian paternalism* is ''an approach that preserves freedom of choice, but that authorizes both private and public institutions to steer people in directions that will promote their welfare'' [1]. This form of paternalism has been successfully modifying people's behavior in real-life situations when applied by policymakers and governments [2]–[4]. Following the accomplishments of this approach, researchers from the field of human–computer interaction (HCI) use the concept of *libertarian paternalism* to nudge people towards particular decisions, by using the particular elements of a UI.

Generally, the efficacy of nudging through choice architecture stems from psychological effects and heuristics, which accompany the cognitive processing taking place at the time of interaction. Colloquially speaking, such effects may have both ''negative'' and ''positive'' outcomes. For instance, they can be applied by an agent (e.g., service provider) to deceive a user and profit from their behavior. On the other hand, they may reduce cognitive workload or enable a user to further reflect on the decision at hand.

The concept of nudges is sometimes perceived as controversial and criticized as unethical and detrimental to autonomy. The dispute over the ethical aspects of nudging is not the subject of this research (for readers interested in information on ethics of nudging, we recommend [5], [6]). Instead, the current work focuses on the fact that it is practically

The associate editor coordinating the review of this manuscript and approving it for publication was Peter Langendorfer.

impossible to create a UI that enables fully autonomous choices. Every design informs and guides a user to perform a particular action. Hence, the knowledge of the psychological effects that are actively engaged in decision-making is crucial for all choice architects and UI designers.

Such knowledge could also advance the work of privacy UI developers and designers. Privacy, a complex notion that is difficult to fully comprehend even by experts, can be misinterpreted by people using technology. Potential risks to privacy, methods of data processing, privacy policies, and any other information related to data collection may be easily overlooked by the user because their main goal is to use an application or purchase a product. Therefore, in this systematic literature review, we focus on the psychological effects investigated in past privacy research to examine which of them effectively alter privacy-related attitudes or behaviors. Additionally, the present review identifies the visual cues (nudges) applied in the privacy research that has led to privacy-enhancing or privacy-deteriorating actions. Finally, the current work emphasizes recommendations for future research on the role of psychological effects in privacy decisions. Specifically, it indicates the methodological aspects aiming to improve research quality and produce results that could be used as a backbone of privacy UI designs.

II. BACKGROUND

Past work around privacy decision-making has identified many factors that influence privacy behaviors. One of the more comprehensive overviews of the complex relationship among the constructs impacting privacy decision-making is provided by Smith *et al.* [7] and Dinev *et al.* [8]. Based on an extensive literature review, the authors of these two publications propose a conceptual model: APCO (Antecedents → Privacy Concerns → Outcomes). The original model contains the following constructs: (1) *antecedents* (e.g., individual characteristics, contextual factors) that shape (2) *privacy concerns* that result in specific (3) *behavioral outcomes* (e.g., information disclosure) [7]. Overall, the model presents the many elements that influence privacy concerns. The model shows that multiple factors influence the relationship between concerns and the actual behavior (e.g., privacy calculus with cost and benefit analysis, trust).

Further, it demonstrates that various behavioral intentions and behaviors around privacy decision-making might be observed, and they are multi-levelled (e.g., decisions of an individual, decisions of a group) [8]. The limitation of the original APCO model is the reliance on the assumption that people are solely rational decision-makers, in an economic sense. Additionally, privacy decisions must be fully informed, that is they are a result of an in-depth analysis caused by external stimuli [8]. However, as we discuss next, past work demonstrates that privacy decisions are not always an ''expected-utility'' rational.

Privacy Paradox:

Such ''irrational'' privacy decisions have been coined in the literature as the *privacy paradox*, the gap between privacy attitude and behavior. The paradox was discussed as early as 2001, in the HP Laboratories report concerning online shopping and loyalty cards [9]. According to the report, a series of in-depth interviews revealed that people express concerns about being tracked by companies; yet they are willing to sacrifice their privacy for a little gain. Since then, many studies has demonstrated the existence of the *privacy paradox* throughout different contexts. For instance, Norberg *et al.* [10] showed an inequality between the declared willingness to disclose information and the actual disclosure (higher than previously stated) in the commercial context. Hughes-Roberts demonstrated that privacy concerns do not accurately predict social network behaviors [11]. On the other hand, in the review of the *privacy paradox* research, Kokolakis showed that the existence of a paradox is debatable, as shown in studies that identify a positive relationship between privacy concerns and protection behaviors [12].

Among the arguments that explain the *privacy paradox*, Kokolakis [12] listed different interpretations of the phenomena, context (behaviors vary between contexts, e.g., dependence on the type of information), and different methods used to examine the *privacy paradox* (e.g., online surveys, experiments). To further explain the *privacy paradox*, Kokolakis proposed three approaches: economic-based (privacy calculus), social theory (e.g., social collective), and cognitive biases and heuristics. Similarly, Dinev *et al.* revised the APCO model, and the updated version includes psychological effects [8]. Specifically, the revised model was extended to contain the level of cognitive effort required to carry out cognitive processing.

A. DECISION-MAKING

The inconsistency between privacy attitudes and behaviors originates in the general processes that take place during decision-making. Traditionally, the economic theories applied to explain judgment and decision-making assumed that people make their choices by maximizing a utility function and accurately accounting for co-occurring constraints or preferences. However, research from psychology and behavioral sciences reveals that the classical economic approach is not always sufficient [13].

1) THEORETICAL EXPLANATION OF ATTITUDE–BEHAVIOR RELATIONSHIP

One of the approaches applied to explain non-normative behavior is with the dual-process theories. This class of theories, simplified, assumes a distinction between two kinds of thinking, often referred to as System 1 and System 2. The first one is fast and intuitive, and the second one is slow and analytical [14], [15]. The standard division into System 1 and System 2 was criticized in the context of higher cognitive processes [15]. The critique originates in the vagueness of the terminology, which tends to indicate that there are only two modes of processing. However, from a neuroscientific point of view, such assumptions are incorrect because, for example,

System 1 refers to multiple processes in the brain. Hence, we follow the terminology proposed by Evans and Stanovich and call for Type 1 and Type 2 processing, instead [15]. Type 1 means that the process is intuitive, is autonomous, and does not require the involvement of working memory. Type 2 is reflective and requires working memory.

At first, one could assume that the Type 1 processing will always lead to ''bad'' thinking, while Type 2 will result in the optimal solution. As Evans and Stanovich [15] have argued, such assumption is incorrect, and this presumed goodness or badness is interchangeable between the processing types. Further, the optimal level of Type 1 processing depends on the environment, that is, whether it is benign or hostile [15]. We articulate this argument because the contrast of the environment is essential for our work. The benign environment contains cues that are useful for the mechanisms of Type 1 processing, the signals that have been previously exercised by the mechanisms of Type 1 processing.

In contrast, the hostile environment does not contain well-practised cues, leading to attribute substitution. This means that an individual assesses a specific target attribute of an object by substituting the different attributes of that object. This is a *heuristic attribute* that automatically and first comes to mind [16]. Apart from attribute substitution, the environment might be hostile if agents deliberately trigger responses of Type 1 processing to gain an advantage. For instance, the advertisement of products in the supermarket may exploit the capabilities of Type 1 processing through a specific way of displaying products on shelves, here aiming to maximize the agent's revenue.

Other approaches have been proposed to explain decision-making processes, with most of them being derived from the critique of the dual-process theories. For instance, Kruglanski and Gigerenzer proposed a unified theory of judgment (UTJ) [17], assuming that both the intuitive and deliberate judgments form rules. These rules depend on cognitive capabilities, as well as recognition memory, and may lead to either optimization or satisficing (heuristics). According to the UTJ, the same rule applies when either an intuitive or deliberate decision is made. Another alternative to the dual-process theories is Cleeremans and Jiménez's dynamic graded continuum (DGC) [18]. Although it is not a theory per se, rather a framework that could be applied to assess the dual-process theories, it contrasts with the dual-process theories in some ways. In short, the DGC states that differences in reasoning originate from the differences in representations. This approach distinguishes between implicit and automatic reasoning, while the dual-process theories use these terms interchangeably. Depending on the quality of the representation, the reasoning changes on a continuum, from implicit through explicit to automatic. Because none of the alternative approaches has been recognized as more reliable than the dual-process theories, in the current work we follow the dual-process assumptions and use them as a bedrock for our motivation and research questions.

In the dual-process approach, the results of the judgments and decisions associated with Type 1 processing are mostly attributed to different psychological effects: biases and heuristics, especially when decisions take place under risk or uncertainty [19]. The influence of psychological effects is substantial and also applies to experts (e.g., professionals of some sort), as long as they are thinking intuitively.

The impact of intuitive thinking has been demonstrated in many studies, ranging from psychology and behavioral science [20] to neuroscience [21], [22]. Confirmatory findings show that psychological effects guide decisions; hence, these effects are frequently applied in the design of choice architecture. Perhaps one of the most significant promoters of such solutions is the aforementioned concept of *libertarian paternalism*. *Libertarian paternalism* has recognized as a legitimate for a choice architect to change people's behavior to improve their life, health, and well-being [3]. It is *libertarian paternalism* that gave rise to the mechanism of *nudge*. As explained by Thaler, a *nudge* is ''any aspect of choice architecture that alters people's behavior in a predictable way, without forbidding any option or significantly changing their economic incentives'' (p. 6, [3]). The concept of nudging choice architecture has been proven effective; hence, it is commonly applied, particularly by governments and policymakers. For instance, companies use behavioral economics to increase employees' savings or apply status quo bias to ensure retirement plans enrolment [2]–[4]. Similarly, governments use a default option for organ donation, or shops display first the healthy products in the cafeteria to increase their consumption [2]–[4].

2) PSYCHOLOGICAL EFFECTS AND DIGITAL ENVIRONMENTS

The gap between attitude and behavior in the digital context might be altered through UI designs. Visual designs influence how users perceive and interact with technology [23]. Further, as we stated, it may be impossible to design a user interface that is entirely neutral and does not affect the steps that a user takes to complete their action [24]. Hence, choice architects/designers must be aware of the potential biases or heuristics that take place during decision-making.

Over the past few years, with the growing reliance on technology, the concept of digital nudging has received more attention. It has been recognized that online decisions are prone to the same psychological effects as offline decisions. Further, digital nudges have the power to alter users' choices at the point of decision-making [25]. Even the slight adjustments in either the content or visual display of information may lead to changes in behavior.

In the context of online environments, research provides guidelines, best practices and frameworks for the design of digital nudges. For instance, Schneier *et al.* presented a life cycle for designing nudges, one corresponding to human-centred design (HCD), including steps such as defining the goal, understanding users, designing the nudge, and testing it [25]. Additionally, they provided examples of what

type of choice (behavior) can be influenced by a specific heuristic and how (through which particular user interface elements) [25]. For instance, the binary choice might be altered by status quo bias and predicted with the use of default radio buttons or checkboxes. Discrete choice (e.g., the choice of two products) may be changed with primacy and recency effects caused by the particular positioning of alternatives (earlier –primacy; later –recency). Other heuristics that could be triggered with UI designs are middle-option bias, anchoring (e.g., slider endpoints), social norms (e.g., display of popularity, honesty codes), or loss aversion (e.g., limited availability).

Similarly, Meske and Potthoff researched psychological effects in the context of persuasive design [26]. The overall goal of their work was to develop a model that could be used to access and design nudging environments in a structured manner. The proposed model contains three phases. First, the analyzing phase establishes who will be nudged, which psychological effects will be exploited, and what the goals of the nudging are. Second, the designing phase grounds which psychological effects, individual characteristics, and proprieties of the system should be considered. Third, the evaluating phase that ensures the fulfilment of the following criteria: freedom of choice, respect for preferences, unchanged incentives. To define the model, Meske and Potthoff performed a literature review. The review identified elements of digital nudging, with an emphasis on the difference between nudging and persuasive design. The main difference here being that persuasive technology does not predict people's behavior, and does not use coercion or deception [26]. Specifically, authors have identified the following mechanisms applied in nudges: (1) anchoring; (2) customized information (tailoring); (3) decision staging (tunnelling); (4) default settings; (5) framing; (6) informing; (7) limited time window; (8) praise and reward (gamification); (9) priming; (10) reminders; (11) simplification (reduction); (12) social influence; and (13) warning. Although Meske and Potthoff [26] determined the literature related to some of the psychological biases, their work was not exhaustive, and authors have acknowledged that their work was a work in progress. To the best of our knowledge, no follow-up work evaluating the proposed model has been carried out.

Mirsch *et al.* focused on the development process proposed by Schneider *et al.* [25] and carried out a systematic literature review to gain an in-depth understanding of the mechanisms that underlie digital nudging [27]. Specifically, the review targeted the identification of the psychological effects that previous research examined in the context of choice architecture, libertarian paternalism, behavioral economics, and online environments. In 65 publications considered for the final review, Mirsch *et al.* identified 20 psychological effects. Their analysis demonstrated some of the identified effects and presented their definitions. Additionally, research has shown examples of nudges and psychological effects to which the nudges relate [27]. We discuss the results of the review performed by Mirsch *et al.* towards the end of the current paper because they are the core of our analysis.

A more recent systematic overview of digital nudges was presented by Caraban *et al.* [28]. Their work also focused on the concept of nudging, specifically its applicability in research on human–computer interaction. This work identified 23 mechanisms of nudging developed in HCI. These mechanisms are clustered into the following six categories:

1) Nudges that *facilitate* decision making by reducing cognitive effort (exploiting status quo bias)
2) *Confronting* nudges that aim to pause action by eliciting a doubt (exploiting regret aversion bias)
3) *Deceiving* designs (exploiting, e.g., decoy effect)
4) *Social influences*, exploiting human nature the effects of conformity and social expectations
5) *Fear* nudges that elicit emotional feelings of loss, fear, or uncertainty
6) *Reinforcement* nudges aiming to reinforce behaviors through a continuous presence in an individual's thinking.

The results are discussed in the context of decision-making, specifically concerning reflective (Type 2) and automatic mind (Type 1) and transparent and non transparent nudges. Caraban *et al.* apply categories of nudges previously defined by Hansen and Jespersen [29]. These categories are (1) interventions that are transparent and facilitate consistent choice (Type 2); (2) interventions that are transparent influencing behavior (Type 1); (3) non-transparent interventions, which manipulate choice (Type 2); and (4) non-transparent manipulation of behavior (Type 1). Caraban *et al.* [28] presented design considerations related to some of the identified psychological effects. Additionally, they mapped the findings against Fogg's model of behavior, assuming that three factors lead to behavioral change – motivation, ability, and triggers [30]. Based on this, Carban *et al.* defined three groups of nudges that may alter behavior: (1) *facilitator* nudges found to simplify user's task; (2) *sparks* to increase the motivation for behavior; (3) *signals* that give a reminder about the task.

3) PSYCHOLOGICAL EFFECTS IN ONLINE PRIVACY AND SECURITY

The concept of *libertarian paternalism* and nudging is common in the literature on online privacy and security. Many scholars applied findings acquired from the research on psychological effects to study privacy-related behaviors (e.g., information disclosure) or to explain behavioral inconsistencies (e.g., *privacy paradox*) [31]–[35]. Gerber *et al.* [36] carried out a systematic literature review to identify the most influential predictors of privacy behaviors, aiming to explain the factors that cause a *privacy paradox*. According to the findings, some of the biases alter behavior. For instance, the optimism bias is a moderate but significant predictor of privacy-protective behaviors, and the affect has a similar influence on behavioral intentions. Further, their results confirmed that social norms have an impact on what information should be shared on social networks.

Over the last couple of decades, a significant discussion of nudges in privacy and security was presented in the works by Acquisti *et al.* [6], [37]. For instance, in [37], authors discussed the dichotomies between privacy attitudes and behaviors and concluded, that privacy decisions are the results of the interplay of many mutually exclusive factors. However, they emphasized the role of what they call *"hurdles"* encountered by consumers, especially in online environments. Among those *hurdles* are information asymmetry, bounded rationality, as well as some cognitive biases and heuristics (e.g., immediate gratification, status quo).

The concept of *hurdles* has been further addressed in a more recent work of Aquisti *et al.* [6]. This review of past studies presented a comprehensive overview of soft paternalism and nudging techniques applied in technology to assist users in their privacy- and security-related choices. The review defined the dimensions of nudging pointing at specific *hurdles* that certain nudges mitigate or exploit. The authors grouped nudging into six dimensions: *information, presentation, defaults, incentives, reversibility,* and *timing*. These dimensions originate from Thaler and Sunstein's acronym of NUDGES: iNcentives, Understand mappings, Defaults, Give feedback, Expect error, Structure complex choices [3].

The *information* dimension is related to feedback and education and aims to reduce information asymmetry and demonstrate realistic risks. Within this dimension, the following *hurdles* are listed: asymmetric and incomplete information, availability heuristic, bounded rationality, optimism bias, and overconfidence. The second dimension, *presentation*, provides contextual cues in the UI that reduce workload and convey the levels of risk. As its sub-dimensions, the authors outlined framing, ordering, salience and structure. The *hurdles* addressed in *presentation* are loss aversion, optimism bias and overconfidence, representativeness, post-completion errors, anchoring, availability heuristics, and bounded rationality. The third dimension defined in [6] is *defaults*, which reduce users' efforts by configuring the system according to the users' expectations; as anticipated, the targeted *hurdle*, in this case is the status quo. The next dimension is *incentives*, which motivate users to behave following their preference; this dimension exploits loss aversion and hyperbolic discounting. The fifth dimension is *reversibility (error resiliency)*, which reduces the impact of mistakes. The authors did not name any specific *hurdles* that are targeted in this dimension. Lastly, *timing* aims to nudge at the right moment; there are no specific *hurdles* listed in this dimension because all of them may be applied at a particular time.

III. RESEARCH QUESTIONS

Even with the large number of studies that have explored issues around privacy-related decision-making, to the best of our knowledge, no work provides a comprehensive view of UI design and the applicability of psychological effects. Specifically, there is no systematic literature review that considers past empirical work and investigates how heuristics and biases alter attitudes or behaviors. Hence, in the current research, we fill this gap and aim to address the following research questions:

RQ1: Which psychological biases and heuristics were applied in the past research to design privacy interactions?

RQ2: How effective were they in altering users' attitudes and behaviors?

RQ3: Are there particular visual cues that trigger responses of Type 1 processing through psychological effects?

To a certain extent, the answers to these questions are provided in the research described in the Background section (Section I), particularly in the review by Aquisti *et al.* [6]. However, our work aims to provide a systematic review of the existing literature instead of a descriptive and selective view of past research. Additionally, our work focuses on studies that deliberately have investigated psychological effects. Lastly, we aim to cover the time gap between the work of Aquisti *et al.* and the current state-of-the-art because their review was completed in 2015. We believe that within the last three years, the research on privacy and privacy nudges produced some valuable work becasue of the increasing number of privacy invasions, as well as new legal requirements, for instance, the EU General Data Protection Regulation [39].

IV. METHODS

To answer the research questions, we conducted a systematic literature review following the framework defined by Okoli and Schabram and by Okoli [38], [40]. We chose this framework because it integrates guidelines on systematic literature review suitable for multidisciplinary work, covering fields such as software engineering, sociology, economics, and more. According to Okoli and Schabram ''for a review to be scientifically rigorous'', all of the steps presented in Figure 1 are essential [38].

After completing step 1 and defining the research questions, we created a detailed protocol. The protocol describes the review strategy, selection criteria and procedures (screening and quality appraisal), data extraction, synthesis, and writing. Further, the protocol includes two annexes. Annex 1 contains definitions of each of the psychological effects selected for the search queries. Annex 2 details the search queries, information about threats to external and internal validity (part of the quality appraisal), preliminary data extraction form, and synthesis information. Two independent reviewers were following each step of the protocol. After the completion of each phase, the principal reviewer merged the findings for further discussion.

A. SEARCH CRITERIA

To define the search queries, as a groundwork, we used the literature review by Mirsch *et al.* [27]. Their work aimed to identify the psychological effects underlying the research on nudging. At the time, their publication was the most comprehensive systematic review of nudging in the context of

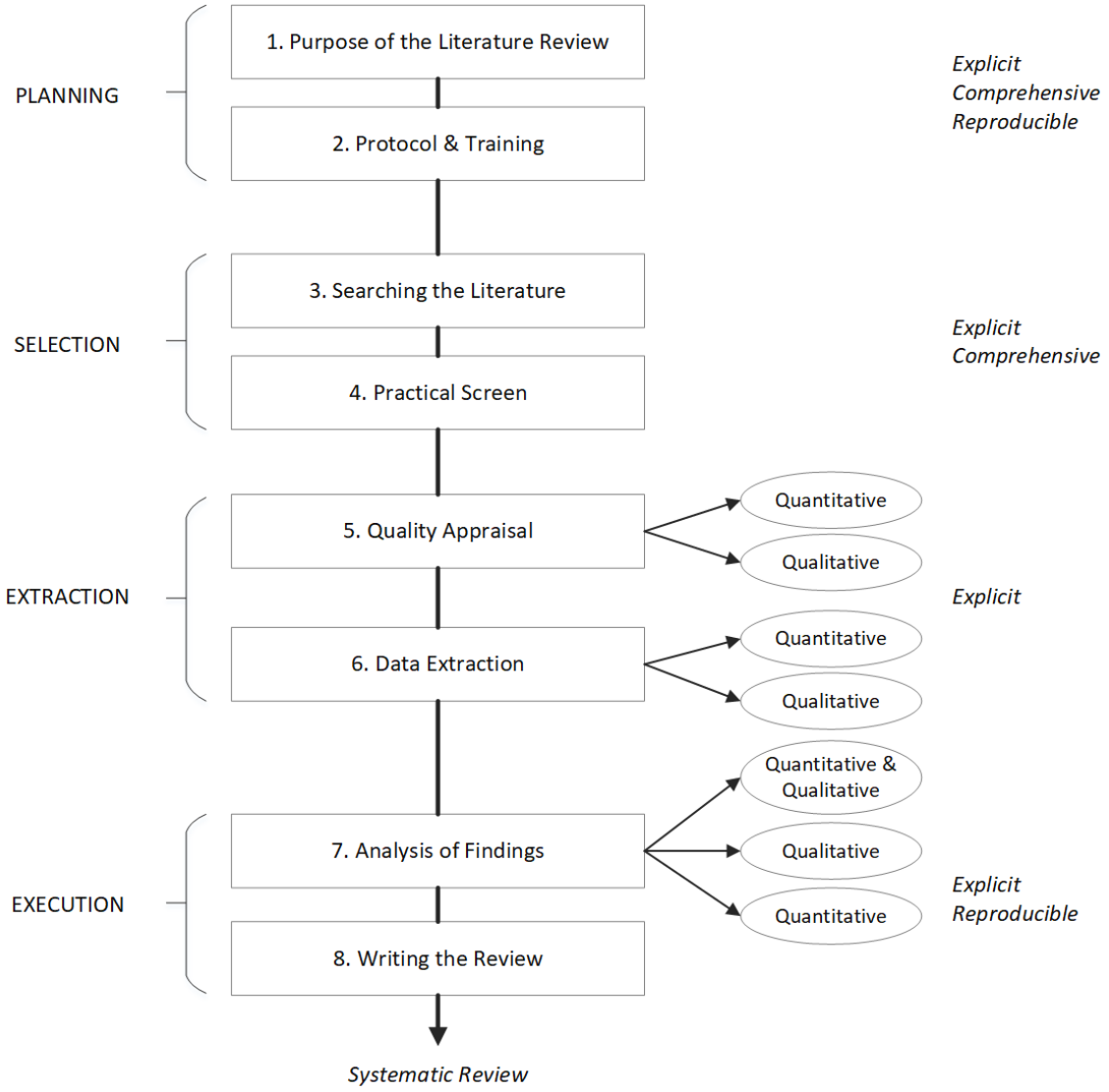

FIGURE 1. Guidelines for a systematic literature review development adapted from Okoli [38].

TABLE 1. Terms used in search queries.

G1:	*G2:*	*G3:*	
Privacy	Interface*	Anchoring	Inter*temporal choice
	UI	Attentional collapse	Loss aversion
		Availability heuristics	Mental accounting
		Commitment	Messenger effect
		Commitment escalation	Overconfidence
		Decoupling	Priming
		Endowment effect	Psychologic* bias*
		Escalation of commitment	Representativeness
		Framing	Social norm*
		Hyperbolic discounting	Spotlight effect
		Image motivation	Status Quo
		Inter-temporal choice	

online interactions. Mirsch *et al.* identified 20 psychological effects, from which we applied 19 to search query keywords (''optimism'' and ''overconfidence'' were found to be interchangeable) [27]. The overall scheme for the literature search in our review was as follows (Table 1):

$$G1 \text{ AND } G2 \text{ AND } G3,$$

where *G1* and *G2* were searched through the meta-data (title, keyword, or abstract), and *G3* was searched anywhere

in the text (when possible, searched through the whole article).

Table 1 presents the details of the search queries. The search was conducted on five databases: ACM Guide to Computing Literature, IEEE, Scopus, dblp, and Web of Science (WoS).[1] These databases were selected because of the multidisciplinary character of our research. Because our research questions consider HCI and UI design and relate to computer science, it was essential to include databases focusing on such works, that is ACM, IEEE, and dblp. Additionally, we used two databases that incorporate the subject of social science: WoS and Scopus. The queries were adjusted accordingly to the requirements of the search query structure defined by each of the databases. Initially, a total of 762 papers were extracted.

V. SELECTION PROCEDURES

Following the method proposed by Okoli [38] and the protocol defined for the current research, the reviewers started with the selection phase. Both reviewers independently searched for literature in the five databases, using previously defined search queries. The results were stored in a file, containing information regarding the number of retrieved works, duplicates, and other search-related information.

A. PRACTICAL SCREEN

To identify work that should be considered in the review, the following inclusion criteria were applied:

- The publication should be a conference proceeding or journal article. Books were excluded from the review because of the following reasons: a. might be unavailable in digital format; b. are less likely to contain all the necessary details of experimental studies; c. may contain subjective synthesis and opinions of authors because they are not subject to the peer-review process. However, any books containing collections of scientific publications were included in the literature search.
- The publication must be in English.
- The publication must be peer-reviewed.
- Publications from the following fields should be excluded: natural sciences and some of the social sciences and other academic fields (e.g., law, anthropology, geography, history, linguistics, political science, and education).
- The publication dates from 2002–2018.

[1]The ACM Guide to Computing Literature "includes all of the content from The ACM Full-Text Collection along with citations, and links where possible, to all other publishers in computing." The database contains 2,853,540 bibliographic records [41]. The IEEE database includes the content of "more than four-million full-text documents from subjects of electrical engineering, computer science and electronics" [42]. The dblp is a computer science bibliography that provides information about major computer science journals and proceedings, comprising 4,866,610 publications [43]. WoS holds more than 161 million records across 254 subject areas, including the Social Sciences Citation Index (SSCI) and Conference Proceedings Citation Index (CPCI) [44]. Scopus includes over 75 million records with over 24,600 active titles and more than 194,000 books. Database comprises the following subject areas: Social Sciences (32%, 9,692 titles), Physical Sciences (27%, 8,102 titles), Health Sciences (25%, 7,468 titles), and Life Sciences (16%, 4,883 titles) [45].

The starting date for the search was set to the year 2002. In this year, Daniel Kahneman received a Nobel Prize in economics. Because Kahneman's work emphasizes issues of dual-process theory, we assumed that after 2002, the interest in research on psychological effects in decision-making would have grown, including privacy-related research.

The practical screening reduced the number of results to 199. The reviewers reached a moderate reliability score of Cohen's $k = 0.42$ (80% agreement).

B. FIRST SCREENING

To establish whether a publication was suitable to answer the research questions, the two reviewers proceeded with an additional step – first screening. This phase required the reviewers to read the articles' titles, abstracts, and keywords.

The first screening criteria were as follow:

- Research must be original and empirical.
- Research should involve the investigation of psychological biases and/or heuristics.
- Research must examine user interface or user interface elements.
- Research must examine privacy-related attitudes or behaviors.

Occasionally, the screening of titles, abstracts, and keywords did not provide sufficient information to satisfy these criteria. In such instances, the whole articles were scanned. Whenever this did not satisfy the criteria, the publications were read in the following order: abstract, conclusion, method, results, and discussion.

The first screening resulted in the sample being reduced to 31 studies. The reviewers reached a moderate reliability score of Cohen's $k = 0.21$ (74% agreement).

C. QUALITY APPRAISAL

When performing a systematic literature review, before the data extraction, it is necessary to identify whether the selected work satisfies the quality requirements. For our work, the quality requirements were derived from Fink [61]. Each reviewer received a quality appraisal (QA) form to help with establishing whether the article should be included in the review. We used a scoring system, in which articles that scored less than four were excluded from the review. Scoring was based on these five questions (each scoring for answers "NO" = 0, "YES" = 1):

1) Does the study address concrete and clearly defined research question(s)?
2) Does the study use valid research methods to address the question(s)?
3) Is the research design described in detail? Detailed research includes "yes" to all of the following:
   - Justification of design
   - Description of its implementation (e.g., random assignment)
   - Explanation of risks from internal validity (e.g., history, maturation, testing, selection)

TABLE 2. List of publications accepted for the review.

ID	Title	Author(s) (year)	Venue type
A1 [46]	"A Field Trial of Privacy Nudges for Facebook"	Wang *et al.* (2014)	Conference
A2 [47]	"Blissfully ignorant: the effects of general privacy concerns, general institutional trust, and affect in the privacy calculus"	Kehr *et al.* (2015)	Journal
A3 [48]	"Capturing, Sharing, and Using Local Place Information"	Ludford *et al.* (2007)	Conference
A4 [49]	"Comparing the configuration of privacy settings on social network sites based on different default options"	Tschersich M. (2015)	Conference
A5 [50]	"Counteracting the Negative Effect of Form Auto-completion on the Privacy Calculus"	Knijnenburg *et al.*(2013)	Conference
A6 [51]	"Display of Major Risk Categories for Android Apps"	Chen *et al.* (2018)	Journal
A7 [52]	"Effects of Security Warnings and Instant Gratification Cues on Attitudes toward Mobile Websites"	Zhang *et al.* (2014)	Conference
A8 [53]	"Engineering Information Disclosure: Norm Shaping Designs"	Chang *et al.* (2016)	Conference
A9 [54]	"Investigating Effects of Control and Ads Awareness on Android Users' Privacy Behaviors and Perceptions"	Wang *et al.* (2015)	Conference
A10 [55]	"Power Strips, Prophylactics, and Privacy, Oh My!"	Gideon *et al.* (2006)	Confrence
A11 [56]	"Privacy Nudges for Mobile Applications: Effects on the Creepiness Emotion and Privacy Attitudes"	Zhang *et al.* (2016)	Conference
A12 [57]	"Privacy Nudges for Social Media: An Exploratory Facebook Study"	Wang *et al.* (2013)	Conference
A13 [58]	"The Effect of Online Privacy Information on Purchasing Behavior: An Experimental Study"	Tsai *et al.* (2011)	Journal
A14 [59]	"The simpler, the better? Presenting the COPING Android permission-granting interface for better privacy-related decisions"	Gerber *et al.* (2017)	Journal
A15 [60]	"Turtle Guard: Helping Android Users Apply Contextual Privacy Preferences"	Tsai *et al.* (2017)	Conference

- Explanation of risks from external validity (e.g., population, ecological validity)

4) Is the sampling method described in detail? The detailed method includes ''yes'' to all of the following:
   - Explicit eligibility criteria
   - Justification of the sample size
   - Explanation of how the sample is assigned to control (if applicable)
5) Is the intervention, proposed approach, proposed interface or design described in detail? The detailed description includes ''yes'' to all of the following:
   - Explicit objectives
   - Activities/interactions are potentially reproducible
   - Results are explained in terms of the objectives

After discussing the merged scores of this quality appraisal, and resolving minor disagreements, 17 papers were selected for final data extraction. The reviewers reached almost a perfect reliability score of Cohen's $k = 0.93$ (96% agreement).

D. DATA EXTRACTION

The two reviewers were provided with data extraction forms created according to the guidelines from Kitchenham *et al.* [62]. The forms required the reviewers to provide both qualitative and quantitative information about each of the 17 publications. The following information was required: source database; application domain (e.g., mobile, IoT, web); design domain (i.e., specific context of UI); research questions/objectives; identified psychological effects; methodology; sample size; participants (e.g., eligibility criteria); methods of analysis; variables studied; primary results; and effect size (if provided).

After completing data extraction, the reviewers agreed to remove two more articles because they did not meet some of the criteria when placed under additional scrutiny during the data extraction phase. Thus, the total number of publications included in the review is 15. Table 2 presents a list of the articles accepted for the review.

1) EXCLUDED PUBLICATIONS

During the quality appraisal and data extraction, a total of 16 articles were excluded. Table 3 presents the list of rejected publications followed by the exclusion rationale. The rationale refers to the lack of fulfilment of a specific QA requirement, which is defined in section V-C. The particular requirement is marked with the number corresponding to each of the five QA criteria.

2) VISUALISING DATA EXTRACTION

After completion of the data extraction, the reviewers classified the identified visual cues into the following categories:

- Cues enhancing privacy attitudes
- Cues enhancing privacy behaviors
- Cues deteriorating privacy attitudes
- Cues deteriorating privacy behaviors

These categories originate from the descriptive findings of our systematic review and are discussed in more detail in section VI. However, to enable swifter identification of a specific visual cue and its capabilities to alter privacy-related attitude and behavior, we display these findings in the form of a diagram (Figure 3). The diagram contains four partitions built on two axes. The axes are not quantifiable, and the distance between each visual cue and the axes does not indicate the cue's strength.

TABLE 3. List of publications excluded at the stage of QA (unfulfilled requirements) with exception of * publications, excluded after completion of the data extraction.

Title [ref]	QA requirement
"ContextContacts: Re-designing SmartPhone's Contact Book to Support Mobile Awareness and Collaboration" [63]	(3)(4)
"Designing for Privacy and Self-presentation in Social Awareness" [64]	* No privacy attitude/behavior
"A User Study of the Expandable Grid Applied to P3P Privacy Policy Visualization" [65]	(3)(5)
"Visual vs. Compact: A Comparison of Privacy Policy Interfaces" [66]	(3)(5)
"Audience Visualization Influences Disclosures in Online Social Networks" [67]	(3)(4)(5)
"Expectation and Purpose: Understanding Users' Mental Models of Mobile App Privacy Through Crowdsourcing" [68]	(1)(2)(3)(5)
"Making decisions about privacy: Information disclosure in context-aware recommender systems" [69]	(1)(2)(5)
"Raising User Awareness About Privacy Threats in Participatory Sensing Applications Through Graphical Warnings" [70]	(3)(4)
"Re-designing Permission Requirements to Encourage BYOD Policy Adherence" [71]	(2)(3)(4)
"Perceptions of Customer Service, Information Privacy, and Product Quality from Semiotic Design Features in an Online Web Store" [72]	(3)(5)
"Addressing Users' Privacy Concerns for Improving Personalization Quality: Towards an Integration of User Studies and Algorithm Evaluation" [73]	(3)(4)(5)
"Exploring User Preferences for Privacy Interfaces in Mobile Sensing Applications" [74]	*No psychological effect
"Increasing sharing tendency without reducing satisfaction: Finding the best privacy-settings user interface for social networks" [75]	(3)(4)(5)
"Addressing The Privacy Paradox Through Personalized Privacy Notifications" [76]	(3)(4)(5)
"Fingerprint Recognition on Mobile Devices: Widely Deployed, Rarely Understood" [77]	(1)(3)(5)
"Online Privacy and Aging of Digital Artifacts" [78]	* No privacy attitude/behavior

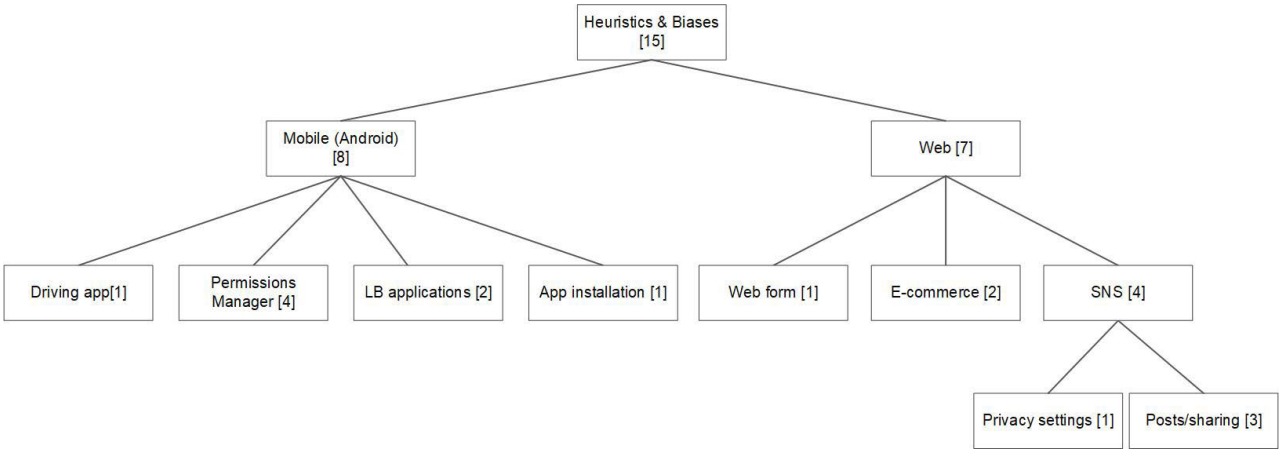

FIGURE 2. Articles containing research about biases and heuristics per technology and context.

VI. RESULTS

The search resulted in 15 publications. Most of the publications are conference proceedings ($N = 11$, 73%). Only four articles are published in journals. Nine articles were found via the ACM database (60%), five via Scopus (33.4%), and one through IEEE.

Eight out of the 15 reviewed publications focus on mobile technology and seven on the web (Figure 2). In the context of mobile technology, half of the papers focuses on permissions management. Concerning the web, four articles examine issues of social network services, investigating the privacy settings of posts/information sharing.

A. PSYCHOLOGICAL EFFECTS

Overall, the review resulted in the identification of 20 psychological effects (*RQ1*). The identified effects are not a mirror image of the search queries. During the review process, we observed that some of the research mentions psychological effects that are not included in the search terms. Table 4 presents the identified psychological effects and their definitions.

We classified the identified effects into two groups. The first group we term *direct* (DIR) because it contains the articles that name and discuss psychological effects directly. The second group we term *deduced* (DED) because it contains the publications that do not directly mention a

TABLE 4. List of psychological effects identified in the search results. * Effects not included in the search queries.

ID	Effect name	Definition
AF*	Affect heuristic	"People make judgements based on the representations of objects and events in their minds that are tagged to varying degrees with affect" ("goodness" or "badness" experienced as a feeling or demarcating a positive or negative quality of stimulus) [79].
AN	Anchoring	Under uncertainty (lack of information), the decisions are biased towards the starting point used to calculate estimates [19].
AV	Availability heuristic	"An assessment of accessibility in which frequencies or probabilities are judged by the ease with which instances come to mind" [14].
DE	Decoupling	Evaluation of costs and benefits may differ, depending on the form of payment (because it may be decoupled from consumption) [27].
DF*	Default effect	Preference of the default option over changing it; acceptance of status quo [80].
EE	Endowment effect	"Tendency when people demand much more to give up an object than they would be willing to pay to acquire it" [81].
FR	Framing	Decision frame can be designed in many ways that control the presentation of the decision problem, thus influencing the final decision [27].
HD	Hyperbolic discounting	Individuals behave inconsistently over time; tendency to value present, smaller rewards more over the future, larger ones [2].
IA*	Information asymmetry	"Acquired from the agency theory developed to address the principal-agent problem, i.e., the difficulties that arise under conditions of incomplete and asymmetric information when a principal hires an agent to pursue the principal's interests" [82].
IC	Inter-temporal choice	The process by which people make decisions about what and how to choose over time [83].
IG*	Instant gratification	One of the trade-offs characterized by sacrificing the future to gain immediate pleasure/satisfaction. In this trade-off, the reward is immediate, and the cost is delayed [84].
IM	Image motivation	The desire to be positively perceived by others as a driver in pro-social behavior [85].
LA	Loss aversion	"The dis-utility of giving up an object is greater than the utility associated with acquiring it" [81].
ME	Messenger effect	"The weight given to information depends on the automatic reactions to the perceived authority of the source of that information" [86].
OP	Overconfidence	"An overestimation of the accuracy of one's judgments, resulting in excessive confidence in them" [6].
PR	Priming	Preparing individuals to the situation where the decision will take place [27].
RE	Representativeness	"Some probability judgments (the likelihood that X is a Y) are mediated by assessments of resemblance (the degree to which X "looks like" a Y)" [16].
SE	Spotlight effect	Tendency to believe that the social spotlight shines more brightly on the individual than it does [87].
SN	Social norms	Unwritten rules are standards that are understood by members of a group that guide and/or constrain behavior [27].
SQ	Status quo	"Humans tend to prefer options that cause no change in their state and/or require no action on their part" [88].

psychological effect. However, the reviewers deduce that the reviewed study might have triggered the use of a particular mental shortcut. The detailed classification of psychological biases in each of the articles is presented in Table 5. It should be emphasized that none of the studies focus only on one psychological effect. That may be the case because these effects are difficult to distinguish, and they frequently correlate with each other.

1) DIRECT

Six articles investigate the specific role of nine biases and heuristics in the context of a web environment: hyperbolic discounting (A1, A12), information asymmetry (A1, A13), anchoring (A4), status quo (A4), default effect (A5), social norms (A8), instant gratification (A12, A13), and overconfidence (A13).

In the context of mobile applications, five publications focus on psychological effects: affect heuristic (A2), instant gratification (A7), framing (A9, A11), social norms (A11), and loss aversion (A14).

2) DEDUCED

Among the 15 reviewed papers, four do not mention any psychological effects directly (A3, A6, A10, A15). Regardless, they were kept in the review process because there was a strong basis for the assumption that design triggers heuristics or biases in the participants' decision-making.

The two reviewers deduced the following effects among seven studies concerned with web applications: social norms (A1, A12), loss aversion (A1), intermediate choice (A1, A12), image motivation (A1, A12), priming (A4, A5, A8, A10, A12), framing (A5, A8, A10, A12, A13), status quo (A5), messenger effect (A5, A10, A13), decoupling (A10), spotlight effect (A12), hyperbolic discounting (A13), and anchoring (A13).

In the context of mobile applications, among the eight articles, the following effects were identified: social norms (A2, A3, A14), framing (A2, A6, A14, A15), messenger effect (A2, A9, A11, A14, A15), status quo (A3, A9, A11), priming (A3, A6, A7, A9, A11, A15), image motivation (A3), hyperbolic discounting (A7), default effect (A7, A15), and availability heuristic (A7).

B. INFLUENCE ON ATTITUDE AND BEHAVIOR

To answer the second and third research questions (*RQ2*: How effective were [psychological effects] in altering users attitudes and behaviors? *RQ3*: Are there particular visual cues that trigger responses of Type 1 processing through

TABLE 5. Direct (DIR) and deduced (DED) biases per article.

ID	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
PR			DED	DED	DED		DED	DED	DED	DED	DED	DED			DED
FR		DED		DED		DED			DIR	DED	DIR	DED	DED	DED	DED
SN	DED	DED	DED					DIR			DIR	DED		DED	
SQ			DED	DIR	DED	DED			DED		DED				
HD	DIR						DED					DIR	DED		
DE							DED			DED			DED		
ME		DED			DED				DED	DED	DED		DED	DED	
IG							DIR					DIR	DIR		
IA	DIR												DIR		
LA	DED													DIR	
IM	DED		DED									DED			
RE								DED							DED
AN				DIR									DED		
SE												DED			
EE			DED												
IC	DED														
AV							DED								
DF					DIR										
AF		DIR													
OP													DIR		

psychological effects?), a qualitative analysis of the extracted data was performed. As a result, the reviewers identified visual cues (UI designs) that may influence different psychological effects. The attitude or behavior changes caused by visual cues can be classified into two categories: privacy-enhancing and privacy-deteriorating changes. Figure 3 presents an overview of the visual cues that affect changes in privacy-related perceptions or actions according to the proposed classification, with some of the cues carrying both privacy-enhancing and privacy-deteriorating effects.

Table 6 presents a detailed description of the studies that contain visual cues and the effects such visual cues have on attitude or behavior. Overall, 18 visual cues were determined, with two of them having both privacy-enhancing and privacy-deteriorating effects.

1) PRIVACY-ENHANCING CUES

Thirteen visual cues were identified to have a strengthening impact on privacy attitudes and behaviors. One is shown to be effective across web and mobile; six are examined in the context of web and six in the context of mobile applications.

a: WEB AND MOBILE

''Salient/comprehensive privacy information'' is a subject of studies in A13 [58], A14 [59] and A15 [60]. In the context of the web (i.e., online shopping), A13 [58] empirically tested whether the display of prominent privacy information has an impact on users concerned about privacy. The researchers applied an experimental design in the context of online shopping (two different products: batteries and a sex-toy). The participants were divided into three further groups (exposed to privacy information, no privacy information, and irrelevant information). The results showed that the participants in the privacy condition were more likely to purchase from a website with privacy icons and with ''better'' privacy policies. Additionally, the participants were willing to pay more for privacy. They seemed to differentiate between the levels of privacy protection offered by websites according to the displayed information. The authors mentioned *immediate gratification, optimism bias,* and *information asymmetry*, with the latter being the most prominent psychological effect triggered in their study. Considering the design of the study, the way of presenting privacy information, as well as the potential cognitive processes present during purchasing, we assumed that other effects might have been present. Explicitly, we deduced the presence of *hyperbolic discounting, framing, anchoring, decoupling,* or the *messenger effect*.

A14 [59] focused on ''salient information'' in the context of the Android permission granting at the time of install. The goal of the work was to compare a previously proposed UI for permission settings, a then-current Android manager with the newly designed interface. Through an experimental design, the participants were presented with a decision: they had to select one of three apps in three different contexts (Sudoku, email, and QR code applications). The experiment's results showed that the most comprehensive UI lead participants to select one of the most privacy-friendly applications. The authors directly mentioned *loss aversion*. However, it is plausible that such decisions are made because of *framing* and the way the information was presented. Further, ''salient information'' is supported with information about the experts' opinions and reviews of each app. Such UI elements might have facilitated other psychological effects, particularly *social norms* or *messenger effect*.

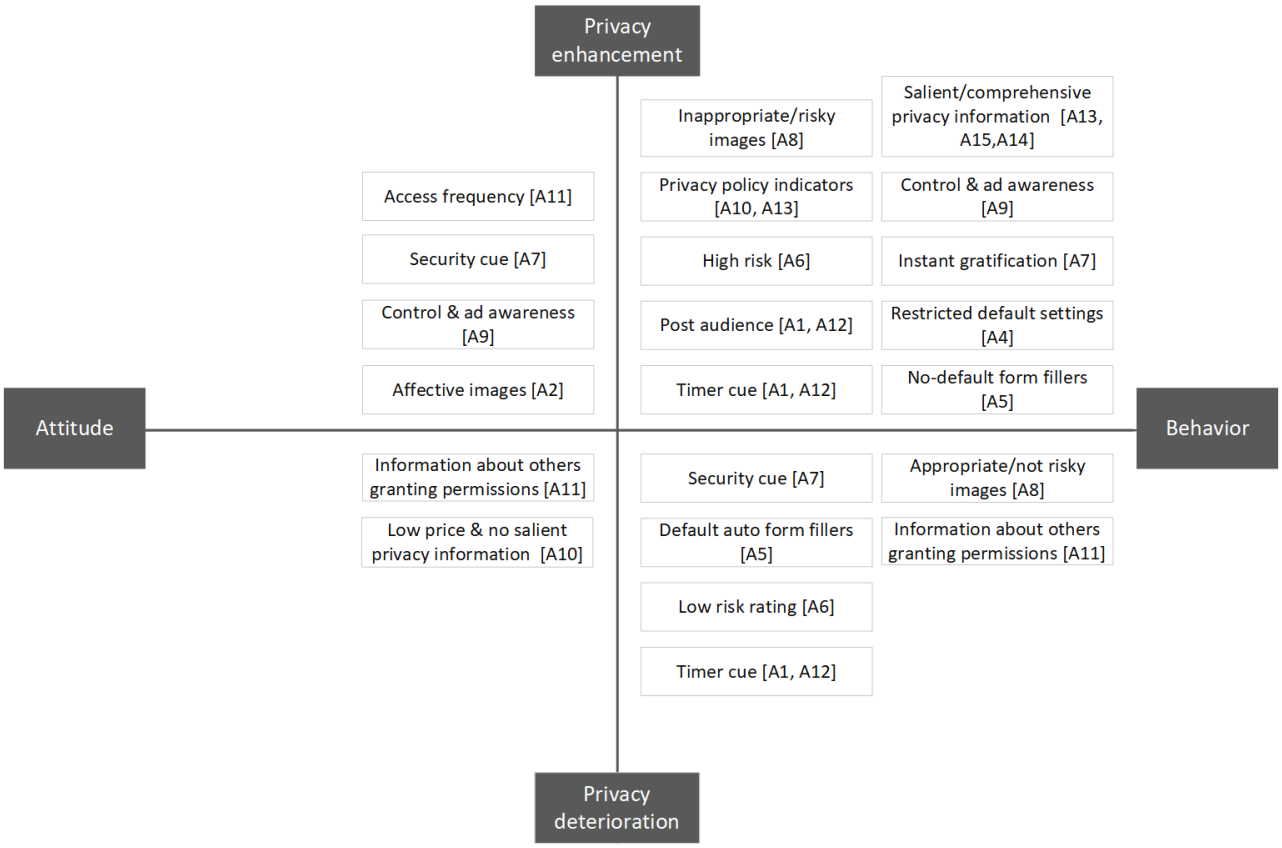

FIGURE 3. **Visual cues investigated in the studies and their "positive" or "negative" influence on attitude or behavior. Note: neither the y-, nor x-axis has a quantitative meaning; hence, the effectiveness of cues does not differ depending on their location against the axes.**

In A15 [60], the researchers performed two experiments, aiming to evaluate the effectiveness of TurtleGuard – a UI for Android permissions' manager. Specifically, their work investigated whether the proposed UI empowered users to make informed privacy decisions. The participants had four different tasks related to mobile applications accessing various phone resources (e.g., which were the most recently accessed, preventing the application from accessing location). The studies showed that "salient information" increased privacy awareness, and improved the participants' mental models about mobile applications and their resource access management. Although the article did not mention any psychological effects that might influence the participants' attitudes and behavior, it is plausible that the visual cue triggered *priming, framing,* or *representatitiveness*.

b: WEB

Similar to "salient information," "policy indicators" were found to enhance privacy. In A10 [55], the researchers ran an experiment to examine the effect of privacy information on purchasing decisions. Specifically, they tested the effectiveness of indicators in two online purchasing contexts: privacy non sensitive (purchasing of a surge protector) and privacy sensitive (purchasing of a box of condoms). The participants were asked to use a search engine to continue with the purchases. During the search, they were exposed to two privacy indications: a salient one ("privacy bird") and privacy notice. The results showed that the willingness to purchase the sensitive product increased when the website had "better" privacy. Such findings indicate that "policy indicators" were noticeable in this particular context. It is plausible that the participants were influenced by the effects of *priming, framing, decoupling,* and the *messenger effect*. "Policy indications" were also examined in A13 [58], which showed their positive effect on purchasing behavior.

In the context of social network services (Facebook), the two studies performed by the same lead researchers showed that the "post audience" (five profile pictures of people who can see the post) and "timer" (time count before a post is shared) cues had a privacy-enhancing effect on attitudes and behaviors. In two field studies, A12 [46] and A1 [57], the authors demonstrated that the "timer cue" decreased the posting of sensitive content. The "post audience" nudge seemed to influence attitude, triggering a reconsideration of posting, changes in privacy settings, and, sometimes, posts' cancellations (Figure 4 presents the nudges studied in A1). An extra nudge studied in A12, a "sentiment cue" (content analysis providing immediate feedback on whether others may perceive the post as negative or positive) based on *social norm* had the least impact on altering decisions; yet,

it triggered a reflection about the post. In the two studies, the authors deliberately explored *hyperbolic discounting, instant gratification,* and *information asymmetry*. Because of the design of the nudges and the social network context, we assume that other psychological effects may have been exploited, for instance, *social norms, framing, priming, image motivation, spotlight effect, intertemporal choice,* and *loss aversion*.

"Restricted default settings" in online social networks are the subject of the quasi-experiment presented in A4 [49]. The study aimed to identify how different privacy settings influence configuration behavior and whether the *status quo*

TABLE 6. Detailed descriptions of the reviewed studies, presenting visual cues and their privacy-enhancing or privacy-deteriorating effects. R*n* – research study (instances when a publication discusses more than one study).

A1	Domain: Web, Social Network Service (SNS)
Objective	Understanding of users' perceptions and interactions with nudges.
Method; Sample (S:)	Field study, Experiment; S:28.
Analysis	Qualitative: Descriptive statistics; Survey in the style of focus groups.
Independent variables	Audience cue; Timer cue.
Outcome variables	Interaction styles: hover over audience profile picture; clicking post now; clicking edit; clicking cancel.
Effect size	N/A
Visual cue	Timer cue; Post audience cue.
Enhancement	More restrictive privacy settings; Posts' reconsideration.
Deterioration	Immediate posting without reflection.
A4	Domain: Web, SNS
Objective	Investigating how status quo bias and anchoring effect influence users with different privacy settings.
Method; Sample (S:)	Quasi-experiment, online; Between-subjects; S:391.
Analysis	Qualitative: Descriptive statistics; Quantitative: t-test, Pearson chi-square.
Independent variables	Control period; Treatment period.
Outcome variables	Four types of interaction: hovering over profile picture; clicking post now; clicking edit; clicking cancel.
Effect size	N/A
Visual cue	Restrictive default setting.
Enhancement	Default option of privacy settings influences individuals' privacy configuration on SNS. Restrictive default settings cause a reduction in willingness to share personal information with large audiences.
Deterioration	N/A
A12	Domain: Web, SNS
Objective	Investigating three nudges related to the Facebook posts (post audience, time, and sentiment nudges) to identify their influence on behavior.
Method; Sample (S:)	Field study; Interviews; S:21.
Analysis	Qualitative: Descriptive statistics.
Independent variables	Three types of nudges; Control; Treatment.
Outcome variables	Posting behavior.
Effect size	N/A
Visual cue	Timer cue; Post audience cue; Sentiment cue.
Enhancement	Timer cue decreases posting of sensitive content. Sentiment nudge leads to reflection about the post. Post audience cue leads to changes in privacy settings and post cancellations.
Deterioration	N/A
A8	Domain: Web, SNS
Objective	Investigating how design choices influence beliefs and behavior.
Method; Sample (S:)	R1: Online, experiment, 2x3x3; S:305; R2: N/A; S:82.
Analysis	Qualitative: Descriptive statistics; Quantitative: Regression analysis.
Independent variables	Image type (risky vs not risky); Pair of new images
Outcome variables	Appropriateness rating; Information disclosure; Advice about information disclosure.
Effect size	N/A
Visual cue	Inappropriate/ risky images; Appropriate/not risky images.
Enhancement	Exposing users to inappropriate images reduces information disclosure.
Deterioration	Exposing users to appropriate images increases disclosure.
A10	Domain: Web, Privacy notice
Objective	Examining the effect of privacy information presented during a product search on purchasing decisions.
Method; Sample (S:)	Experiment; 2x2 mixed design; S:24.
Analysis	Qualitative: Descriptive statistics; Quantitative: chi-square, Mann-Whitney, Wilcoxon tests.
Independent variables	Presence of privacy information; Privacy sensitivity of purchase.
Outcome variables	Choice of an online shop.
Effect size	N/A
Visual cue	Salient privacy indicator (privacy bird); Privacy notice.
Enhancement	Increase in purchasing from sites with better privacy policies (in the context of purchasing sensitive products). Willingness to pay more for products purchased from the sites with better privacy.
Deterioration	N/A

TABLE 6. ***(Continued.)*** **Detailed descriptions of the reviewed studies, presenting visual cues and their privacy-enhancing or privacy-deteriorating effects. R*n* – research study (instances when a publication discusses more than one study).**

A5	Domain: Web, Web-form
Objective	Examining changes in behavioral outcomes during web-form interactions, depending on the auto-fill tool.
Method; Sample (S:)	Quasi-experiment, online; Mixed between-within subject design: 3x3[x4]; S:460.
Analysis	Qualitative: Descriptive statistics; Quantitative: CFA, SEM.
Independent variables	Tool type (TT); Website type (WT); Item type (IT).
Outcome variables	Information disclosure (ID); Perceived risk (PR); Perceived relevance (RE).
Effect size	Main effects on ID: PR $r = 0.245$; RE $r = 0.125$; TT Remove $d = 0.165$; TT Add $d = 0.107$. Interaction: TT and PR: PR x TT Auto $r = 0.361$; PR x TT Remove $r = .371$; PR x TT Auto $r = 0.330$; RE $r = 0.115$. Interaction: TT and RE: RE 0.266; RE x TT Remove $r = 0.285$; RE x TT Add $r = 0.208$.
Visual cue	Auto-fill per default; Auto-fill no-default.
Enhancement	The alternative tools that do not provide immediate auto-fill option increase a website's purpose considerations and reduce disclosure.
Deterioration	Default auto-fill option increases disclosure.
A13	Domain: Web, shopping
Objective	Studying the influence of prominent display of privacy information on privacy-concerned purchasers.
Method; Sample (S:)	Experiment, between-subject design; S: "$272 - 12.5\%$," as reported in A13.
Analysis	Qualitative: Descriptive statistics; Quantitative: Fisher's exact test, Chi-square, t-test.
Independent variables	Three conditions: No privacy indicator; Irrelevant information present; Privacy information present.
Outcome variables	Choice of online shop; Price paid.
Effect size	N/A
Visual cue	Salient, comprehensive privacy information; Privacy policy information.
Enhancement	Salient privacy information encourages purchasing from sites with better privacy policies. Increase in purchasing in privacy concerned manner. Significant influence of privacy information on the price, participants willing to pay more for purchasing from privacy-preserving sites.
Deterioration	N/A
A15	Domain: Mobile, Permissions
Objective	Designing a new permission manager UI based on ML to empower users to make better privacy decisions.
Method; Sample (S:)	R1 & R2: experiment, online, between-subjects; S1:392; S2:580.
Analysis	Qualitative: Descriptive statistics; Quantitative: chi-square, Wilcoxon; Qualitative reports.
Independent variables	Control, Treatment (using Turtleguard).
Outcome variables	Task 1 (recent location access), Task 2 (Finding granted permissions), Task 3 (Finding background activity), Task 4 (Limiting background activity).
Effect size	R1: Task 1 $\phi = 0.192$; Task 2 N/A; Task 3 $\phi = 0.363$; Task 4 $\phi = 0.509$. R2: Task 1 $r = 0.17$; Task 2 N/A; Task 3 $\phi = 0.414$, ease of use $r = 0.13$, time to complete task $r = 0.22$; Task 4 $\phi = 0.49$, ease of use $\phi = 0.49$; Additional: changes in the dashboard required $\phi = 0.237$.
Visual cue	Salient, comprehensive privacy information.
Enhancement	Increased information awareness; Task completion, such as identifying applications' background activity. In general, the salient design leads to improved permission management activities.
Deterioration	N/A
A9	Domain: Mobile, Permissions
Objective	Examining how control over information disclosure, enhanced ad awareness and apps' context influence disclosure and privacy-related perceptions.
Method; Sample (S:)	Experiment, online; 3x2x3 between-subject; S:447.
Analysis	Qualitative: Descriptive statistics; Quantitative: ANOVA, t-test, MANCOVA, ANCOVA, SEM.
Independent variables	Control (No, Low, High); Ads awareness (Present vs Absent); Context.
Outcome variables	Perceived control; Privacy perceptions; Privacy behaviors (accept/decline; change settings; disclosure).
Effect size	N/A
Visual cue	Control and ad awareness.
Enhancement	Control supported with information about data processing results in increased risk awareness and lesser disclosure.
Deterioration	Control over the information disclosure increases trust, improves the impression of the app, and leads to a higher likelihood of an app installation.
A14	Domain: Mobile, Permissions
Objective	Comparison of different designs of permission settings.
Method; Sample (S:)	Experiment, online: 6x3 mixed design; S:344.
Analysis	Qualitative: Descriptive statistics; Quantitative: ANOVA, MANOVA.
Independent variables	Interface design; Decision scenario.
Outcome variables	Frequency of a correct decision; Subjective helpfulness; Mean decision time.
Effect size	Decision time between the fastest and slowest across interface design $\eta^2 = 0.037$.
Visual cue	Salient, comprehensive privacy information.
Enhancement	Increases privacy decisions.
Deterioration	Decrease in subjective helpfulness.

TABLE 6. *(Continued.)* **Detailed descriptions of the reviewed studies, presenting visual cues and their privacy-enhancing or privacy-deteriorating effects. R*n* – research study (instances when a publication discusses more than one study).**

A11	Domain: Mobile, Permissions
Objective	Studying mitigation of users' cognitive burden during privacy decision-making via nudges.
Method; Sample (S:)	Experiment, online; Between-subjects; S:387.
Analysis	Qualitative: Descriptive statistics; Quantitative: Multivariate GLM, ANCOVA, SEM.
Independent variables	Two types of nudges, control group (no nudge).
Outcome variables	Creepiness; Perceived control; Privacy concerns; Disclosure comfort; Ease of use; Usefulness; Intention to use; Perceived relevance.
Effect size	Effect of the nudge presence on users' perception $\eta^2 = 0.08$. Privacy nudge on ease of use $\eta^2 = 0.02$ and usefulness $\eta^2 = 0.04$ of privacy settings; on perceived control $\eta^2 = 0.02$, relevance $\eta^2 = 0.03$; on intention to use permission-settings $\eta^2 = 0.02$. Main effect of privacy nudge on creepiness $\eta^2 = 0.11$; on sharing data $\eta^2 = 0.04$.
Visual cue	Frequency nudge (how often each type of data is used by an app); Social nudge (percentage of an app users that approve the use of each type of data permissions).
Enhancement	Frequency cue: the app perceived as more difficult to use, less useful, and uncomfortable to share information with the app. Struggle to accept the "real truth" of mobile apps' data usage.
Deterioration	Social nudge: increases user's comfort; reduces privacy concerns, elevated information disclosure, decreased emotional creepiness.
A2	Domain: Mobile, Driving app
Objective	Investigating the interplay between affective and rational thinking in a privacy-sensitive context.
Method; Sample (S:)	Quasi-experiment, online; 2x2 between-subjects; S:414.
Analysis	Qualitative: Descriptive statistics; Quantitative: t-test, CFA, correlations, SEM.
Independent variables	Affect; Information sensitivity.
Outcome variables	Institutional trust; Privacy concerns; Perceived risks; Perceived benefits; Perceived privacy; Intention to disclose.
Effect size	N/A
Visual cue	Affective images (positive, neutral).
Enhancement	Positive affect reduced influence of information sensitivity on risk perceptions. Higher risk perception because of positive affect.
Deterioration	N/A
A3	Domain: Mobile, Location Based Service
Objective	Identifying which heuristics are used to decide upon sharing location-related information.
Method; Sample (S:)	R1: Field study; S1:20; R2: Interviews and task completion; S2:29.
Analysis	Qualitative: Descriptive statistics; Interviews quota.
Independent variables	Location sharing application.
Outcome variables	Place type; Sharing behavior; Decision heuristics; Utility.
Effect size	N/A
Visual cue	Information shared/not shared by others.
Enhancement	No effect
Deterioration	N/A
A6	Domain: Mobile, App install
Objective	Examining the effectiveness of different representations of the major risk categories to integrate the intermediate level of risks representation into the app interaction.
Method; Sample (S:)	R1, R2 and R3: Quasi-experiment, mixed design; S1:379; S2:359; S3:385.
Analysis	Quantitative: linear mixed-effect regression, ANOVA.
Independent variables	Three risk categories; Four design types (bar graph and table, horizontal vs vertical).
Outcome variables	Risk rating; Response time.
Effect size	R1 – Risk rating: Representation graph (RG) $\eta^2 = 0.089$; personal privacy (PP) $\eta^2 = 0.420$; monetary loss (ML) $\eta^2 = 0.375$; device stability (DS) $\eta^2 = 0.244$. Interactions: PP x ML $\eta^2 = 0.083$, PP x DS $\eta^2 = 0.040$, ML x DS $\eta^2 = 0.036$, PP x ML x DS $\eta^2 = 0.019$ R1 – Response time: Representation type (RT) $\eta^2 = 0.129$, Display orientation (DO) $\eta^2 = 0.028$, RT x DO $\eta^2 = 0.074$. R1– Risk concerns x Risk category: PP $\eta^2 = 0.030$, ML $\eta^2 = 0.032$, DS $\eta^2 = 0.012$. R2 – Response time longer for graphs than tables $\eta^2 = 0.019$; Representation type x orientation $\eta^2 = 0.026$; Bar graph: response time shorter for horizontal display $\eta^2 = 0.008$; Table: response time shorter for vertical display $\eta^2 = 0.011$. R3 – Response time: difference between horizontal and vertical orientation $\eta^2 = 0.036$.
Visual cue	Intermediate risk scores (device stability, monetary loss, personal privacy): High-risk rating; Low-risk rating.
Enhancement	High risk-rated applications are less likely to be selected for installation.
Deterioration	Lower risk scores lead to app selection, reducing concerns about privacy.
A7	Domain: Mobile, LBS
Objective	Studying interaction effect between instant gratification cues and a security cues with users attitudes and behaviors.
Method; Sample (S:)	Experiment, online; Factorial design, 2x2; S:220.
Analysis	Qualitative: Descriptive statistics; Quantitative: ANCOVA, SEM.
Independent variables	Instant gratification cue; Security cue.
Outcome variables	Attitude towards website; Perceived trust; Behavioral intention to visit; Perceived threat; Information disclosure.
Effect size	N/A
Visual cue	Security cue; Instant gratification cue.
Enhancement	Instant gratification cue lowers trust towards a website.
Deterioration	Security cue increases disclosure.

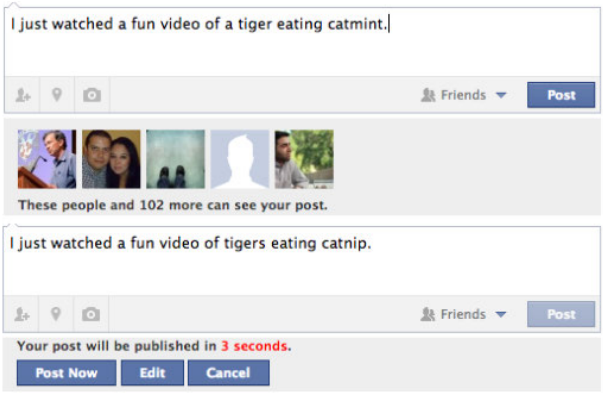

FIGURE 4. Privacy nudges: ***post audience*** and ***timer*** from A1 [46].

and *anchoring* effects influence users with restrictive privacy settings. Thus, this work focused directly on testing the role of psychological effects. The experiment consisted of two groups of participants (one with restricted privacy settings fixed to 'Only me' and the second one with public settings fixed to 'Everyone') who could change 14 different privacy settings of their SNS accounts. The results showed that default options influenced how individuals set their privacy configuration. Additionally, the findings demonstrated that ''restricted default settings'' had the potential to reduce willingness to share personal information.

Another example of a web-based visual cue associated with social network services is ''inappropriate/risky images,'' which was examined in A8 [53]. Through an online experiment, the authors aimed to identify how design influenced perceptions about social norms and as a result affected disclosure behaviors. In the experiment, the participants were rating the riskiness of images, whether they perceived them more or less appropriate. Next, they were asked questions measuring information disclosure. The results showed that among the people exposed to ''inappropriate/risky images'' information disclosure was reduced compared with the people exposed to ''normal'' images. Apart from directly investigating the effects of *social norm*, it is assumed that *priming* and *representativeness* also may have affected the results. Such an assumption is based on the study design, specifically on the way participants were exposed to the set of different images and the resemblances of the stimuli.

''No-default form fillers'' is another type of visual cue tested in the context of the web and might have privacy-enhancing influence. Through an online quasi-experiment, A5 [50] aimed to examine behavioral changes resulting from web-form interaction. Specifically, the researchers compared three form auto-completion tools (1) traditional auto-completion, (2) remove (allows the removal of certain information from the autofill), and (3) add (allows adding auto completion to form fields). These were tested in four different contexts (form filler, blog, job search, and health insurance). The results demonstrated that the alternative tools that did not auto-fill the form increased considerations regarding the website's purpose and effectively reduced information disclosure. The research directly studied the *default effect*. Because of the design of the study (presentation of the form fillers) and potential perceptive reactions to the forms, it is assumed that other psychological biases might have been triggered, such as *framing, status quo, priming,* and the *messenger effect*.

c: MOBILE

A2 [47] focused on a driving assistance mobile app to investigate the interplay between affective and rational thinking concerning privacy. Through an experimental design, the research applied ''affective images'' (positive and neutral) to identify whether they have an impact on risk-taking and perception of benefits of disclosure. Specifically, the participants were assigned to one of the four groups presented with different vignettes (low or high sensitive information must be provided to obtain the optimal results from an insurance policy) and accompanying affective cues (positive or neutral). The results showed that a positive affect had the potential to influence risk perception by reducing the impact of information sensitivity. Additionally, the risk was perceived higher among respondents exposed to ''affective images.'' Apart from the *affect*, this visual cue might have triggered *framing, social norm,* and the *messenger effect*. Possibly, the visual frame affected the risk-taking and perceptions of disclosure. Similarly, there is the potential that the participants were constrained by the social standards that require specific reactions to the affective stimuli or automatic reactions to the stimuli because of the perceived authority.

FIGURE 5. Treatment conditions applied in the study investigating instant gratification and security nudges, adapted from A7 [52].

A7 [52] presents ''instant gratification'' and ''security'' cues to investigate how they interact with attitudes and behaviors. In an online experiment, the participants were exposed to one of four visual cues presented as a mobile website for a restaurant recommendation system. They were being asked to register for the website's services (Figure 5). Here, the ''instant gratification'' cue lowered trust towards the website. The ''security'' cue increased perceived threats and lowered intentions towards the website. Apart from *instant*

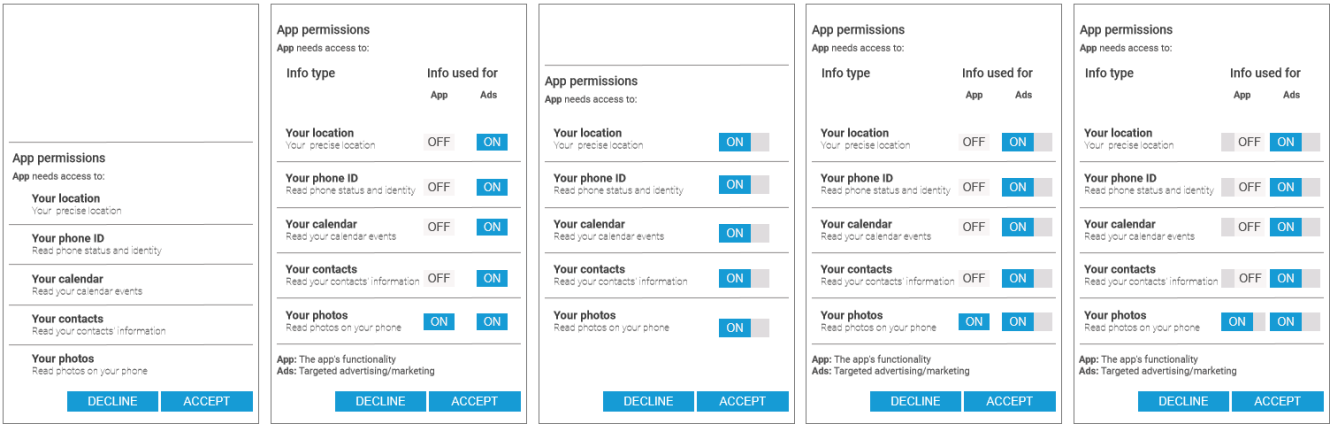

FIGURE 6. User interface designs adapted from A9 [54]. From left: no control, ads awareness absent; privacy dialog: no control, ads awareness present; low control, ads awareness absent; low control, ads awareness present; high control, ads awareness present.

gratification, it is possible that *hyperbolic discounting, priming, decoupling,* and *availability heuristic* may have been triggered by the visual stimuli. Such an assumption is based on the study design and the way that visual cues present information.

A ''high risk'' display was investigated in A6 [51]. Through three online experiments, this research aimed to evaluate the effectiveness of different representations of major risk categories – the intermediate level of risk representations (personal privacy, monetary loss, and device stability) in the context of mobile app installation. In the first experiment, the participants were asked to assign the risk rating to each of the different risk displays. In the second and third experiments, they were asked to select an application to install, meaning they were able to choose between the applications with the different visualization of the risk display (vertical bar graph, horizontal bar graph, vertical table, horizontal table). According to the results, the bar graphs yielded higher risk ratings when compared with the table representations, and the horizontal bars were more efficient than the vertical ones. Among the participants who reported to be more privacy concerned, the risk ratings were influenced by the score in the personal privacy category. Similarly, people concerned with monetary loss were more affected by the risk score of the monetary loss category. Applications with *high risk* cues were less likely to be chosen to install. However, there appeared to be no difference between the intermediate-risk categories. There were no psychological effects directly investigated in the study. Nonetheless, considering the different visualizations of risks scores, it is plausible that *framing* or *priming* could have influenced the participants' decisions.

In A9 [54], the researchers investigated how control over information disclosure, ad awareness, and application context, influence privacy perceptions and disclosure behavior. Using a ''control & ad awareness'' cue, the experiment tested behavioral interactions with the app permissions manager upon the application install (Figure 6). The results showed that providing users with control supported with information about data processing (such as ads information) had an impact on risk perception and information disclosure. Specifically, risk awareness increased, and less information was being disclosed. According to the authors, the study investigated the influence of *framing*. However, based on the study design (exposure to differently framed information) and the way information was presented, other psychological effects may have been present, such as *status quo, priming,* or the *messenger effect*.

An ''access frequency'' cue was investigated in A11 [56]. The research objective was to identify whether privacy decision-making could be mitigated with privacy nudges and how an emotion (creepiness) influences such decisions. In an online experiment, the participants were assigned to one of the three mock-ups of mobile application permission request interfaces. The interfaces contained no nudge, a ''social'' nudge, and a ''frequency'' nudge (Figure 7). The results showed that an ''access frequency'' cue changed the perception of applications. The participants perceived applications with this cue as more difficult to use and less useful and felt uncomfortable to share information. The participants' awareness rose, and they appeared surprised, finding it hard to accept that the applications could access phone resources so frequently. This work focused on *framing* and *social norms*. Additionally, it is possible that because of the visualizations applied, *status quo, priming,* and the *messenger effect* were also triggered.

2) PRIVACY DETERIORATING CUES

Seven visual cues were identified to weaken privacy attitudes and behaviors. Four of them were examined in the context of web applications and three in the context of mobile apps. Some of the visual cues and experiments were described in the section above. In such instances, below, we describe only the resulting changes in attitude or behavior.

a: WEB

In A10 [55], the authors showed that a visual cue presenting ''low price & no salient privacy information'' influenced

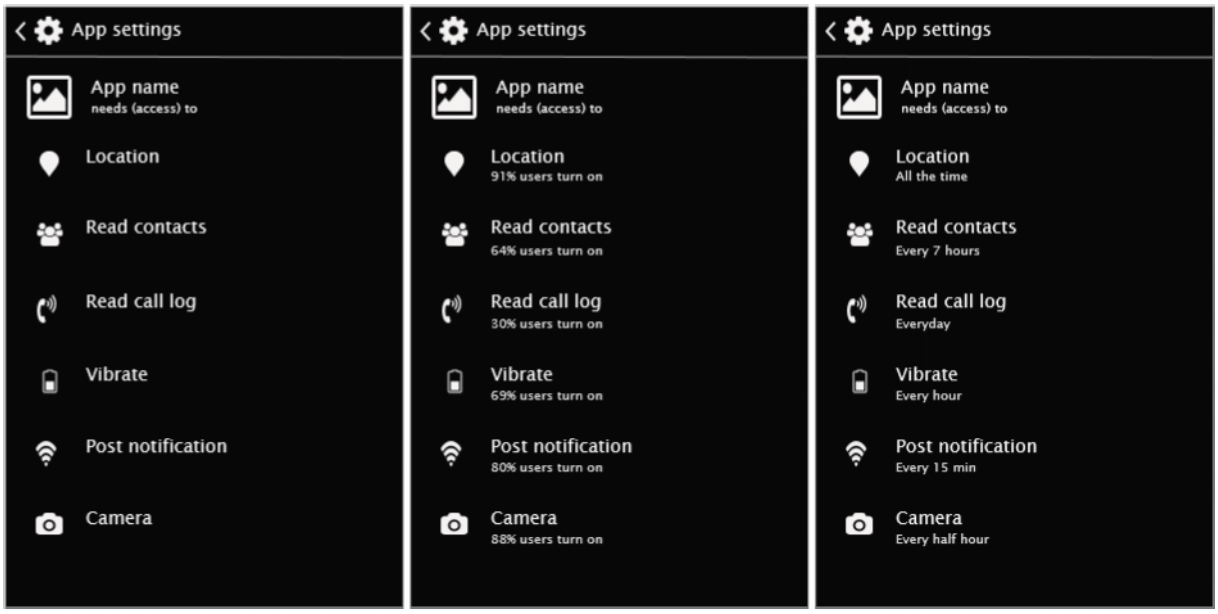

FIGURE 7. User interfaces adapted from A11 [56]. From left: no nudge; social nudge; frequency nudge.

online purchasing behavior. Precisely, it can be deduced from the study results that the participants exposed only to the price information were steered towards purchasing from websites with the best price (the cheapest), regardless of the websites' privacy handling. Whereas, as discussed above, when the salient privacy information accompanies price information, such decisions become more rational, triggering privacy concerns and more cautious behavior.

The ''timer cue'' investigated in A1 [46] and A12 [57] was shown to have both privacy-enhancing and privacy-deteriorating effects. Specifically, the results demonstrated that the ''timer cue'' led some people to share their post quickly without reflecting on such action. Additionally, the cue raised some negative feelings, such as unease, being afraid to proceed with the action, and an annoyance (when users knew what they wanted to post).

''Appropriate/not risky images'' were studied in A8 [53]. The results demonstrated that the participants exposed to such visual stimuli disclosed more information than those who were not exposed to it. The participants presented with less-provocative images, had a higher rate of responding to questions that were less (e.g., ''How often do you hold the door open for someone?'') and more (e.g., ''Did you ever have sex with someone who was too drunk to know what they were doing?'') intrusive in nature. The answers to such questions were required to create a fictional social network profile in the context of the study.

Finally, the ''default auto form fillers'' were shown to influence behavior (A5 [50]). Specifically, when compared with alternative options, the ''default auto form fillers'' lead to increased disclosure through the *default effect*.

b: MOBILE

The ''security cue'' investigated in A7 [52] was shown to increase information disclosure. On the other hand, the same study demonstrated that a lack of a ''security cue'' affected threat perception. Specifically, when there was no visual cue, fewer threats were perceived by the user. Similarly, when the ''security cue'' was not present, people tended to have a stronger intention towards the website.

In the context of mobile app installation, A6 [51] established that the ''low risk rating'' cue influenced application selection. The results showed that applications with lower risk ratings were more likely to be chosen for installation. As much as this may sound like a privacy enhancement, it could be used to manipulate users towards installing an application, e.g., false presentation of low risk score to encourage a user to install a malicious app. Additionally, such a cue might have an impact on attitudes, reducing privacy concerns.

The ''information about others granting permission'' cue was tested in A11 [56]. This cue, exploring the *social norm* effect, increased the overall comfort of an interaction. However, it decreased privacy concerns and raised information disclosure. Additionally, it decreased emotional creepiness caused by the ''frequency'' cue. As a result, it led to less careful permission management behavior.

While discussing *social norms*, it should be mentioned that one of the publications included in the review is not listed among privacy-enhancing or privacy-deteriorating cues. In A3 [48], the authors investigated heuristics that people use when deciding upon sharing the information related to location-based services. The research results showed no effect of previously shared location or shared messages regarding the place visited in the past on sharing similar information by others. Although the research does not mention directly any of the psychological effects, it seems clear that the use of the information such as the previous experiences of others might influence the *social norm* bias. Considering the study design, and the visualizations of information, it is

plausible that *status quo, priming, image motivation,* and the *endowment effect* are also present in the study.

VII. DISCUSSION

Privacy-related interactions frequently take place in a hostile environment. Online service providers may deliberately trigger responses of Type 1 processing to mislead users in taking action that maximizes an online provider's revenue. On the other hand, the hostile environment might be created unintentionally by choice architects and UI designers. In the light of the recent legal changes (e.g., the General Data Protection Regulation [39]), as well as social pressure on online service providers resulting from the scandals around privacy and security violations (and their ensuing consequences in different social spheres), the design of digital interactions should no longer lead to the abuse of personal information collected through misleading UI designs. In the current research, we aimed to investigate how UI design, triggering Type 1 processing through psychological effects, may increase data collection (resulting in privacy deterioration). Nevertheless, we also revealed and exhibited evidence as to how nudges can be applied to improve personal information management (privacy enhancement).

Through a systematic review, we investigated past research that examined the role of psychological biases and heuristics in the context of altering privacy-related attitudes and behaviors. Following the research questions, we identified 20 psychological effects that were a subject to privacy UI studies (*RQ1*). As a result of qualitative data extraction, we identified the visual cues that conceivably may influence Type 1 processing and classified them according to the impact they may have on privacy-enhancing or privacy-deteriorating attitudes or behaviors (*RQ2, RQ3*).

In this section, we discuss the research findings concerning the frameworks presented in the Background section (Section I). Additionally, we attempt to categorize the identified visual cues. Further, we sketch a critical summary of the retrieved works, providing recommendations for the designs of privacy UI studies. We conclude with a summary of our findings, limitations, and future directions.

A. PSYCHOLOGICAL EFFECTS, NUDGING AND PRIVACY

The past frameworks and guidelines on the design of digital nudging have discussed most of the psychological effects identified in the current research. For instance, Schneier *et al.*, and Meske and Potthoff listed *status quo, anchoring, social norms, framing, informing, loss aversion, priming,* and *default effects* to be essential for the design of digital nudges [25], [26]. Our findings extend their framework, increasing the number of psychological effects, discussing additional mental shortcuts, such as *instant gratification, overconfidence, affect, decoupling,* the *messenger effect,* and more. Most importantly, our research lists psychological effects that could be applied in the design of a specific category of nudges – nudges for privacy. On the other hand, we show that three of the initially searched for psychological effects were not identified in our review: *commitment escalation, attentional collapse,* and *mental accounting*.

Further, our findings can be categorized using the framework proposed by Caraban *et al.* [28]. According to their research, there are six clusters of nudges: *facilitating, confronting, deceiving, social influencing, eliciting fear,* and *reinforcing*. The privacy-related visual cues identified in our work can be assigned to the following classifications:

1) *Facilitating* cues that aim to influence privacy-related decisions by reducing mental effort are *default auto-form fillers* (A5) and *restricted default settings* (A4).
2) *Confronting* privacy visual cues, which aim to trigger reflection and pause an interaction, are *timer cue, sentiment cue, post audience cue* (A1, A12), *privacy notice* (A10), *intermediate risk scores* (A6), *security cue, instant gratification* (A7), and *frequency nudge* (A11).
3) *Deceiving* cues that could be used to create the so-called ''dark patterns'' of privacy interactions are *control and ad awareness* (A9) and *appropriate/not risky images* (A8).
4) *Social influence* visual cues contain *information shared/not shared by others* (A3), *post audience* (A1, A12), and *social nudge* (A11). Notwithstanding, it must be noted that one of the analyzed studies demonstrated that the social cue does not have any impact on privacy-related decisions.
5) *Fear*-inducing cues include *security cue* (A7), *intermediate risk scores* (A6), and *frequency nudge* (A11).
6) *Reinforcing* cues aiming to trigger an individual's thinking about privacy related actions, are *salient/comprehensive privacy information* (A13, A14, A15), and *privacy policy indicators* (A10, A13).

B. EFFECTS ON ATTITUDE AND BEHAVIOR

The results of the empirical studies analyzed in the current review demonstrate that visual cues carry the potential to change privacy-related attitudes or behaviors (*RQ2, RQ3*). Such cues, if appropriately implemented in the design of privacy UIs, could help diminish the effects of the *privacy paradox*. However, to reduce the attitude-behavior gap, it is crucial to identify *which* nudges and *how* may influence the factors related to attitude, and which may influence the factors related to behavior. Hence, in this section, we divide the visual cues into two categories according to the effect they may have on the factors influencing attitude and behavior. The summary of this classification is presented in Table 7.

1) ALTERING ATTITUDINAL FACTORS

The APCO model lists some of the factors that influence privacy-related attitudes. These attitudinal effects can be influenced by, for instance, *privacy concerns, awareness, risk perceptions, willingness to share,* and *trust*.

According to our analysis, ''salient information'' (A13) about the privacy policy, based on the privacy ratings

TABLE 7. Visual cues and their influence on specific attitudinal and behavioral factors.

Type of visual cue	Attitudinal changes					Behavioral changes					
	Privacy Concerns	Privacy Awareness	Risk Perception	Willingness to share	Trust	Information Disclosure	Application Installation	Privacy Settings	Online Posting	Privacy Aware Purchasing	Paying for Privacy
Salient information [A13, A14, A15]	●	●						●		●	●
Risk information [A6]	●						●				
Affect [A2]			●								
Restrictive default settings [A4]				●							
Frequency nudge [A11]				●							
Instant gratification [A9, A7]					●						
Control & Ad awareness [A9]			●		●	●					
Social nudge [A11]	●			●							
Default autofill [A5]						●					
Appropriate/not risky images [A8]						●					
Security cue [A7]						●					
Inappropriate/risky images [A8]						●					
Privacy policy indicators [A10, A13]										●	●
Post audience [A1]									●		
Timer [A12]									●		
Sentiment nudge [A12]								●	●		

(i.e., estimated ''goodness'' or ''badness'') and privacy reports, has an impact on privacy concerns in the context of online purchasing decisions. On the other hand, ''social nudges'' (A11) in the context of mobile applications permission settings, can reduce privacy concerns and increase the potential for disclosure. Similarly, ''intermediate risks'' information, such as a low-risk score, reduces concerns about privacy.

Further, ''salient information'' affects privacy awareness (A15). In the context of mobile applications, such visual information was shown to influence how people perceive service providers. Specifically, people perceived them in a more privacy-aware manner.

Our results revealed that some visual cues might increase risk perception, which consequently may result in more privacy-protective behaviors. For instance, ''affect'' (A2) was shown to impact the relationship between information sensitivity and risk perception, with the sensitivity of information having less of an influence on risk perception among people in a positive affective state. In general, the study (A2) demonstrated that positive affect may result in higher risk perceptions.

The application of privacy-oriented ''restrictive default settings'' (A4) reduces willingness to share information, at least in the context of social networks. On the other hand, the ''frequency nudge'' (A11) tested in the mobile app environment, decreases willingness to share information through increased feelings of creepiness and discomfort towards service providers frequently accessing different types of information.

Trust is the last ''attitudinal'' factor influenced by some of the visual cues. For instance, the presence of the ''instant gratification'' cue lowers trust toward the website. On the other hand, in the context of mobile apps, applying ''control over information & ad awareness'' (A9) leads to an inverse effect, resulting in increased trust in the application provider and encouraging users to install allegedly trustworthy apps.

2) ALTERING BEHAVIORAL FACTORS

The most significant changes in behavior relate to *information disclosure*. There should be no doubt that ''default auto-fill'' (A5) for web forms leads to an increase in information disclosure. Although it is a user-friendly feature aiming to decrease cognitive workload and enable faster task completion, it may be used ''against the user'' to collect information that is not required for a service's functionality. Similarly, exposure to ''appropriate/not risky images'' (A8) in the context of social networking can be exploited to increase information disclosure. Further, the ''security cue'' (A7) has an unexpected effect on disclosure. Specifically, in the context of social media, the presence of a security warning was correlated with more information being disclosed. Possibly, the disclosed information could have been perceived as non-sensitive information (e.g., number of Facebook friends, Twitter ID). Control over information supported by the ''control & ad awareness'' (A9) cue may lead to

decreased information disclosure. However, the effectiveness of control is context-dependent, that is the visual cue is ineffective in some applications, depending on the data sensitivity or purpose of data collection. The exposure to ''inappropriate/risky images'' influences disclosure in social network settings. Specifically, such a form of priming leads to a reduction in information disclosure. Information disclosure may be increased by a ''social nudge'' (A11). In the mobile context, this type of nudge influences users' comfort and elevates disclosure through a decrease in emotional responses, such as the feeling of creepiness, fear, or discomfort.

Among other behavioral factors influenced by some of the identified visual cues are a willingness to install applications, privacy-enhancing mobile permissions settings, posts cancellations, and purchasing in a privacy concerned manner. One of the most often researched behaviors is the change in privacy settings. For instance, ''salient privacy information'' (A15) in the Android permissions manager encourages users to find information about applications' background activity. Additionally, it enables active changes in permission settings. Similarly, such salient cues enable quicker privacy-protective decisions compared with UIs that contain a less informative privacy display (A14). In the context of social networks, the ''post audience'' nudge, containing pictures of familiar people, potentially influences the restriction of privacy settings (A1, A12), while the ''timer nudge'' leads to a decrease in the posting of sensitive content (A1, A12).

Further, comprehensive privacy information modifies purchasing behavior. In the context of sensitive and personal products, people tend to purchase from an e-commerce provider presenting ''better'' privacy policies (A10, A13). In some instances, people are even willing to pay more for the products sold by an online store displaying prominent privacy information on their website (A13).

C. PSYCHOLOGICAL EFFECTS IN PRIVACY RESEARCH

Our results show that psychological effects applied in a privacy design carry the potential to alter people's decisions. However, most of the results from studies around privacy-related UIs empowering nudging are inconclusive and highly contextual. Even among the studies analyzed in the current review, it is evident that the same biases and heuristics may cause inconsistent outcomes. For instance, social norms can be applied to enhance privacy-protective behaviors. Nevertheless, in a specific context (e.g., sharing location-related information), they are ineffective. Such contradictory results call for systematic research on privacy-related decision-making. Next, we propose recommendations for further research.

a: RESEARCH DESIGN RECOMMENDATIONS

The research recommendations are based on the protocol defined for the current literature review and the content of the reviewed articles, as follows:

1) *Concise definition of psychological effect(s) or heuristic(s) that are the subject of the study.* Past research resulted in reviews (including the current article) recognizing psychological effects that, when implemented in the design of UIs and choice architecture, can nudge/alter attitude or behavior. Researchers should primarily focus on studies of these previously identified biases and heuristics, to produce a more coherent view of how such effects should be implemented in the design of privacy UIs.
2) *Improved study design.* Among the 15 reviewed studies, only nine were based on an experimental design, which is slightly over half of the articles selected. Many of the papers were excluded from the review partly because of lacking experimental design. The absence of an experimental or quasi-experimental design increases the possibility of error, that is a study that potentially identifies that a psychological effect is triggered by a UI design alters attitude or behavior cannot be conclusive. Considering the complexity of judgment and decision-making processes, controlling for error is crucial to enhance the validity and reliability of the results. Such control, when possible, should be implemented in the study design. Alternatively, it could be applied at the stage of data analysis in the form of statistical control.

   Further, other types of study designs could improve research on privacy UIs, such as field or longitudinal studies.
3) *Sampling method.* The QA applied in the current review demonstrated that the sampling procedures were rarely justified. The lack of such information leads to decreased applicability and generalizability of the results. The past work around decision-making defined multiple factors that influence how decisions are made. For instance, demographic characteristics, cultural background, and contextual dependencies frequently influence the results of statistical analyses. Therefore, to evaluate the reliability of quantitative studies, it is necessary to justify the examined sample size and desired population. Only a couple of articles reviewed provided such information, ensuring the suitability of their statistical analyses, increasing experimental reliability and validity.
4) *Replicability.* The studies aiming to investigate the impact of visual stimuli on a human subject should provide clear instructions and access to all materials necessary to replicate the study. It is crucial considering that the studies included in the current review frequently originate from psychology or cognitive research, fields in which a reproducibility crisis has been shown to affect the quality of scientific results [89].
5) *Attitudinal or behavioral outcomes.* Research on privacy-related decision-making must become more transparent about particular factors that are under investigation. In the reviewed articles, the researchers rarely

TABLE 8. Directly studied (DIR) psychological effects and their influence on attitudinal and behavioral changes, per domain.

DIR studied psychological effect	Attitudinal changes					Behavioral changes					
	Privacy Concerns	Privacy Awareness	Risk Perception	Willingness to share	Trust	Information Disclosure	Application Installation	Privacy Settings	Online Posting	Privacy Aware Purchasing	Paying for Privacy
Framing [A11, A9]			▲	▲		▲					
Social Norms [A12, A8, A11]	▲					▲		●	■		
Status Quo [A4]				■				■			
Hyperbolic Discounting [A1, A12]									■		
Instant Gratification [A7, A12, A13]	■				●				■		■
Information Asymmetry [A13]	■								■		■
Loss Aversion [A14]								▲			
Anchoring [A4]				■				■			
Default Effect [A5]						■					
Affect [A2]			▲								
Overconfidence [A13]	■										■

▲ mobile ■ web ● both mobile & web

considered attitudinal or behavioral explanations of constructs central for their studies. Such information could help system developers and designers to estimate how particular elements of UI may affect users' decisions.

6) *Other methodological issues.* The current review leads to the conclusion that many studies around privacy-related decisions lack essential methodological explanations. The most prominent issues are the lack of clear objectives or research questions that could enable understanding of the research designs and methods used. Further, the absence of clear objectives makes it cumbersome to discuss the results, and communicate them to the reader. Additionally, there seems to be a misunderstanding of some of the methodological terminology, for example, researchers calling an experiment "controlled" when that experiment controls for a variable yet does not contain a control group. Similarly, some of the articles described studies as between-subject designs while applying the mixed design. Lastly, there seem to be a tendency to invent new instruments measuring psychometric constructs. Such instruments, without an appropriate validation, may incorrectly measure latent variables, leading to false assumptions.

The studies about privacy-related decision-making relate to psychological research. Considering the replicability crisis in psychology [89], and similar problems in other fields [90], our design recommendations aim to improve the current state of the privacy research. We believe that a greater emphasis should be placed on replication studies that investigate the psychological effects identified in past research instead of focusing on new phenomena. Replication studies could enhance findings of the role of psychological biases in privacy-related interactions, making them more conclusive, consistent, and systematic. Such findings could be easily applied in the privacy UI designs.

Consequently, we think that research based on our recommendations will give rise to more consistent and reliable results. Effectively, this will contribute to building a systematic body of knowledge around modifying privacy-related attitudes and behaviors.

D. SUMMARY OF CONTRIBUTIONS

In the current article, we identified the papers that directly (DIR) or indirectly (DED) studied 20 psychological effects in the context of privacy interactions. Our results show that some of the psychological effects were triggered with the visual cues that influenced privacy-related decisions, both at the attitudinal and behavioral levels. To improve future research, we proposed a set of research design recommendations. Moreover, we postulate that psychological effects that have been identified as deduced (DED) should be considered in future studies as primary research questions. Specifically, future work should focus on these effects in the context of the attitudinal and behavioral changes listed in Table 7.

Further, our work provides an overview of directly studied psychological effects and how they affect attitudinal and behavioral changes. In Table 8, we present a list of the psychological effects classified as DIR and the context in which they were examined in the reviewed articles (both domain- and outcome-wise). We believe that researchers interested in the study of privacy interactions can use these findings to quickly identify gaps in the body of knowledge and draw ideas for future research.

E. LIMITATIONS

The present work is not free of limitations. First, the search queries are based on a previous literature review. The search for psychological terms could be extended and could consider a more substantial amount of psychological effects, for instance, those identified by Caraban *et al.* [28]. However, the inclusion of the generic term ''psychological bias'' should have mitigated this limitation and enabled screening for articles that did not include specific psychological effects from the original search queries. Second, to keep the scope of the current research within reason and to adhere to the research rationale, the search was limited to five databases. In the future, it may be advisable to extend the search to databases specializing in social science, specifically psychology and behavioral sciences.

VIII. CONCLUSION

The current literature review applied a systematic methodology to identify empirical studies that had investigated psychological effects resulting from digital interactions in the context of privacy. In the 15 publications selected for the review, our research identified visual cues that have the potential to facilitate psychological effects and as a result contribute to changes in attitudes or behaviors. Drawing on our findings, the present article demonstrates how particular visual cues tend to function, specifying their privacy-enhancing or privacy-deteriorating capabilities.

The review ties its results to current findings of the design of digital nudges. The research extends existing frameworks by the inclusion of additional psychological effects identified in the 15 articles. Additionally, it presents recommendations for future studies aiming to examine psychological biases and heuristics in privacy-related decision-making. The recommendations address issues of research quality, and intent to improve studies' design to enable greater applicability and generalizability of the results.

Overall, the contributions of this review are two fold. First, the results may help researchers improve their research designs, as well as provide them with insights on the visual cues used in privacy-related studies. Second, the findings may be used by developers and designers of privacy choice architectures and UIs to improve their designs and form a more accurate predictive insight regarding planned and potential interactions.

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