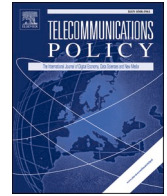




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## Overlooked – Presence and awareness cues in the metaverse

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### ABSTRACT

This article examines how “Presence and Awareness Cues” (PAACs) such as read receipts, online status indicators, and typing notifications shape data disclosure in computer-mediated communication (CMC), with particular focus on emerging metaverse contexts. PAACs are often overlooked in current policy debates despite their potential to reveal sensitive behavioral, relational, and even physiological information. Drawing on a broad review of related literature, we propose a conceptual framework outlining four pillars of mediated presence (PAACs, content, aesthetics, and fidelity), offering policymakers a technology-agnostic lens for anticipating developments in augmented and virtual settings.

We then present findings from a six-country survey (n = 18,358) examining whether and how users notice, interpret, and control PAACs, as well as their willingness to share additional cues in advanced AR/VR environments. Results indicate that most users recognize PAACs across diverse online services and adapt their behavior accordingly. These insights underscore potential policy gaps when biosignals such as heart rate and gaze become integral to projected availability or emotional states.

We conclude that balancing consumer protection with user-friendly interfaces calls for more nuanced oversight, especially as the European AI Act and related legislation could inadvertently limit the adoption of intuitive PAACs. Future research should probe how users negotiate these cues in fully interoperable metaverse environments, particularly when multiple identities or cross-application interactions come into play.

### 1. Introduction

The disclosure of personal information to providers of digital devices and services has drawn increasing attention from activists, policymakers, and regulators in recent years. While much of this scrutiny focuses on overt and covert data collection, this article highlights an underexplored dimension: the technological affordances we term “Presence and Awareness Cues” (PAACs). Such cues (read receipts, online status indicators, typing notifications) can prompt both intended and unintended disclosures in computer-mediated communication (CMC), yet they are often absent from mainstream discussions on consumer protection.

This shortcoming becomes particularly salient as the internet grows more immersive, integrating physical and digital layers into a seamless user experience. Although the terminology for this shift varies, e.g., “Web 4.0” (European Commission, 2023), “immersive technologies” (OECD, 2025), and “metaverse” (World Economic Forum, 2024), each describes the next phase of digitalization. In that phase, virtual and real objects and environments fully interconnect and communicate in real time, creating genuinely intuitive and

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immersive experiences for end users. For clarity and in line with prevailing public and scholarly discourse (Yang et al., 2025; Zhou et al., 2024), we use “metaverse” throughout this article.

In an emerging metaverse context, PAACs may evolve substantially if they begin to incorporate biosignals to display inferred availability, attention, or even emotional states. While sensors, devices, and software necessary to implement these augmented cues already exist, consumer-protection policies have so far paid little attention to their implications. The resulting gap risks leaving users unprepared to navigate new forms of mediated presence that could blend seamlessly into everyday encounters or enrich face-to-face (F2F) interactions with personal data drawn from heart rate, gaze tracking, or other physiological indicators.

To address these gaps, this article introduces a four-pillar framework spanning PAACs, content, aesthetics, and fidelity that provides a technology-agnostic lens for examining how presence and awareness are projected and perceived in digital environments. By integrating scholarship from computer-supported cooperative work (CSCW), human-computer interaction (HCI), and communication studies, we reveal how the interplay of these pillars shape user experiences and data disclosure risks. Grounded in an empirical survey of more than 18,000 respondents across six countries, our analysis highlights the critical role of AR/VR familiarity in amplifying or mitigating the privacy implications of advanced ways of projecting and perceiving presence in mediated environments. In doing so, we move beyond existing discussions on data collection and privacy, offering policymakers and practitioners a practical conceptual tool for guiding consumer protection in both current and future metaverse contexts as well as extending emerging metaverse ethics discussions (Al-Kfairy et al., 2025; Effing, 2024).

The remainder of the article is structured as follows. Section 2 introduces our conceptual frame, situating PAACs within a broader review of how presence and awareness operate in mediated environments. Section 3 consolidates these perspectives into a unified conceptualization of PAACs, paving the way for the research questions outlined in Section 4. In Section 5, we detail our data and methodology for investigating PAAC-related behaviors across six countries. Section 6 then presents our empirical results, while Section 7 interprets these findings and discusses their implications for policy and regulation. Finally, Section 8 concludes by offering recommendations for policymakers, developers, and other stakeholders charged with shaping the metaverse in a manner that fosters user empowerment and safeguards consumer interests.

## 2. Conceptual frame

In F2F interactions, humans rely on a wide array of verbal and nonverbal cues to project their own presence and awareness and to detect that of others. From identifying potential interlocutors in one’s immediate environment to gauging who is both willing and able to engage, these cues shape the initiation and flow of conversation as well as participants’ behaviors and emotional responses. Cultural norms, social contexts, and personal attributes can influence their interpretation. However, the employment of such cues is constrained by physical and temporal factors like co-location and timing, alongside the inherent limits of human perception and attention.

Users of CMC encounter parallel challenges. They too must determine whether a potential interlocutor is present, aware, and willing to communicate. Purposefully embedded cues, which we refer to as PAACs, help establish reciprocal understandings of presence and availability in digital spaces. Unlike their F2F counterparts, digital PAACs transcend physical and temporal boundaries. We therefore do not view PAACs merely as digitized imitations of F2F cues, but as cues in a new medium that can, in certain respects, surpass the capabilities of physical proximity. In taking this position, we build on the foundational work of Hollan and Stornetta (1992) and align with Walther’s Social Information Processing (SIP) Theory (Walther, 1992, 1996; Walther & Whitty, 2021), particularly its “hyperpersonal” perspective, which contends that mediated channels can exceed the effectiveness of F2F communication.

Since successful remote communication and collaboration require coordination (Berlage & Sohlenkamp, 1999; Dourish & Bellotti, 1992; Lynch et al., 1990), even the earliest telegraph and telephone systems embedded rudimentary presence indicators. Classic

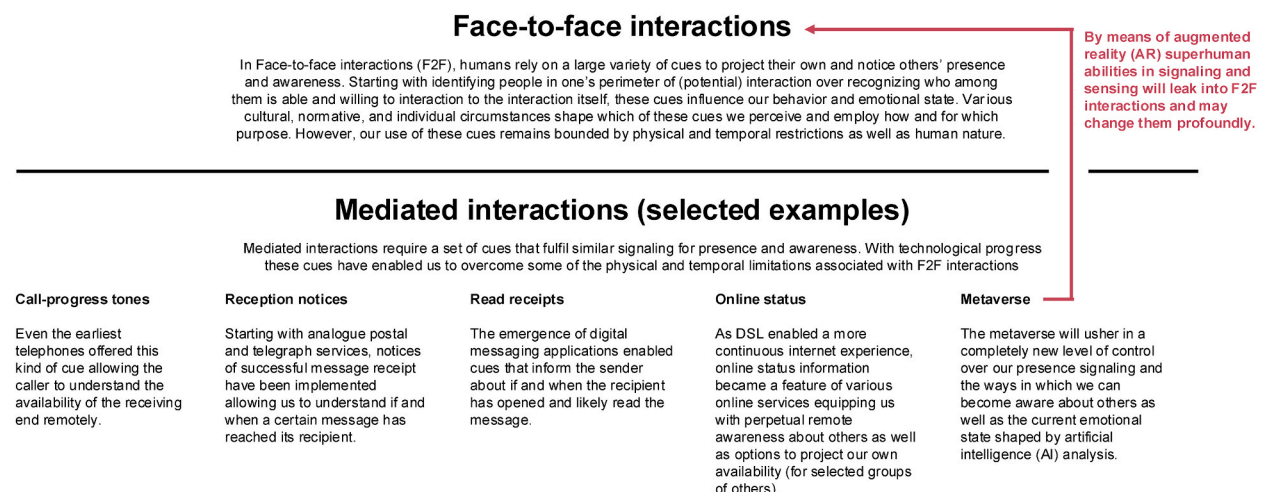


Fig. 1. Presence and awareness cues (PAACs) in F2F and mediated interactions.

call-progress tones, for example, instantly revealed whether the distant party was available, providing a novel form of remote “sensing.”

As computer networks matured and expanded, increasingly sophisticated presence cues emerged. These include online status, read receipts and typing indicators, which enable the inference of attentiveness, relational closeness, or even emotional tone (Kalman & Rafaei, 2011; Kalman et al., 2013; Kato & Kato, 2015; Kato et al., 2017; Mai et al., 2015; O’Hara et al., 2014).

Alongside this evolution of popular CMC applications, researchers have developed numerous experimental and prototype solutions to augment the feeling of presence in CMC. For instance, they have integrated heart rate data or arousal levels inferred from additional sensors into chat interfaces (e.g. Hassib et al., 2017; Kelly et al., 2018; Liu et al., 2017a, Liu et al., 2017b). To date, these sensor-driven features remain curiosities confined to the lab, yet they prefigure the capabilities that the next wave of digitalization will demand.

In the emerging, fully immersive metaverse, such sensing moves from optional add-on to indispensable infrastructure. Its functions rest on eye-, body-, and gaze-tracking, always-on cameras, ambient microphones, and other sensors (McGill, 2021; Osborne et al., 2023; Tanenbaum et al., 2020). Collectively, they will enable PAACs, including emotion inference, that far exceed the informational bandwidth of F2F interaction. Furthermore, this eventually ubiquitous digital layer will spill into everyday encounters, dissolving the once-clear boundary between computer-mediated communication and in-person conversation. Fig. 1 summarizes this trajectory.

Starting with the earliest computer networks, researchers in the fields of Computer-Supported Cooperative Work (CSCW) and Human-Computer Interaction (HCI) have devoted substantial attention to how users perceive and project presence and awareness in mediated environments (for reviews see: Gross, 2013; Skarbez et al., 2017). Despite this long research tradition, there is no consensus on a single precise definition for the intertwined concepts of presence and awareness. Instead, descriptions and definitions continually shift alongside technological innovation in CMC. Correspondingly, the body of scholarship has become both extensive and fragmented. The next phase of digitalization as described above with its ensuing integration of human activity recognition (HAR) makes it necessary to incorporate yet another substantial stream of literature which further complicates the conceptual landscape.

In this article, we seek to reconcile these perspectives by proposing a pragmatic conceptualization and definition of PAACs with the objective of making them accessible and manageable for policymakers. To that end, we intend to situate PAACs within broader questions of self-presentation and the feeling of “being present” in mediated contexts. For this conceptualization to resonate with current and future digital policy debates, we introduce terminology and an overarching framework for PAAC-related affordances that is deliberately technology-agnostic, making it relevant to legacy, current, and emerging platforms including the metaverse.

### 3. Development of a unified terminology for projecting and perceiving presence in computer-mediated environments

The preceding section has highlighted the pivotal role of PAACs in telecommunications and underscored their critical impact in the metaverse. Building on these insights, we now turn to the task of equipping policymakers and regulators with a clear, pragmatic vocabulary to describe how individuals project and perceive presence in computer-mediated environments. Just like presence is a psychological construct independent of any specific technology (Lee, 2004), this framework and corresponding vocabulary must remain technology-agnostic to be meaningful beyond current CMC implementations.

To this end, we integrate the broad and fragmented literature on presence and awareness from CSCW and HCI research into a unified conceptual framework and corresponding vocabulary. In doing so, we unpack the concept social presence and clarify how PAACs relate to other functions and features commonly described under this umbrella term (e.g. Biocca et al., 2003; Graf et al., 2023; Harms & Biocca, 2004; Kojima et al., 2021). By distinguishing its core dimensions and pinpointing specific affordances that merit future oversight, we lay the groundwork for potential future policy interventions.

|                           |   |  |  |  |
|---------------------------|---|--|--|--|
|                           | <b>Social Signals of Presence and Awareness</b>   | <b>Coding and Decoding of content</b>  | <b>Enacting identities and realities</b>   | <b>Place, Plausibility, and Proximity Illusion</b>   |
| <b>User capabilities</b>  | Identify potential interlocutors and initiate an exchange of information; Interpret PAACs of other users; Manage one’s availability, attention, and activity signals in social contexts.      | Purposeful or phatic acts of information exchange under the constraints of sender – receiver model of communication. | Purposeful or phatic acts of information alteration, augmentation, deprivation, or exclusion.                | The illusion of “being there with the other(s)” manifested in the perception of the participants in the exchange of information. |
| <b>Technical features</b> | Functions and features that register and make accessible the existence, availability, attention, and actions of a user within an interactive system facilitating the exchange of information. | The information exchanged as part of the interaction.  | Functions and features to alter, augment, deprive, or mute content selectively in purposeful or phatic acts. | The degree of accuracy of content presentation across actuated senses in the exchange of information.                            |
|                           | <b>Presence and Awareness Cues (PAACs)</b>  | <b>Content</b>   | <b>Aesthetics</b>  | <b>Fidelity</b>  |

Fig. 2. Unified conceptualization of projecting and perceiving presence in mediated environments including definitions.

For our purpose, the definition of social presence put forward by Harms and Biocca (2004) provides a valuable starting point: “Social presence in a mutual interaction with a perceived entity refers to the degree of initial awareness, allocated attention, the capacity for both content and affective comprehension, and the capacity for both affective and behavioral interdependence with said entity.” Building on their concept, we propose **four pillars** to describe comprehensively how individuals project and perceive presence in computer-mediated environments.

The **first pillar** encompasses the features and functions that establish **users’ initial awareness** of who is available and willing to communicate, as well as those that help **allocate attention and convey comprehension** once an interaction begins (Oemig & Gross, 2007). We define these features and functions collectively as **PAACs**. The **second pillar** focuses on the **deliberate content** of the communication, while the **third pillar**, which we call **aesthetics**, pertains to **how each entity is perceived**, for instance, through avatars, filters, or other visual designs. Finally, the **fourth pillar** in our concept called **fidelity** captures how effectively these elements are delivered, ensuring that **users’ capacity for affective and behavioral interdependence** is supported by stable, high-fidelity connections. Fig. 2 presents definitions for each pillar, along with explanations and examples of their associated affordances.

The concept of affordances was introduced by (Gibson, 1979) and later extended to communication technologies by Gaver (1991, 1992). Affordances, according to Majchrzak et al. (2013), represent “the mutuality of actor intentions and technology capabilities that provide the potential for a particular action.” Gaver (1991) describes the “climbability” of stairs as “a measurable property of the relationship between people and stairs” and therefore an affordance evident through visual inspection, enabling people to judge the effort required to ascend (Warren, 1984).

By contrast, affordances in computer-mediated environments often require user interpretation and may remain hidden from some individuals, causing similar features to yield vastly different outcomes (Fox & McEwan, 2017; Kukshinov et al., 2024; Schrock, 2015). As Gross (2013) argues, awareness is never simply “produced” by technology; rather, it emerges when participants leverage publicly available resources they have learned to recognize. This understanding underscores why our unified framework for projecting and perceiving presence in mediated environments must account for user agency, interpretive processes, and the broader sociotechnical context in which those cues operate. Fig. 2 reflects the concept of affordances by spelling out the pairing of technical features and user capabilities for each of the four pillars. We expand on our reasoning for each of the pillars in the following paragraphs. Aligned with the focus of this article, we devote special attention to PAACs.

To bolster our approach to PAACs, we draw on the extensive scholarship examining awareness and presence. In our definition of PAACs, we thus regard awareness and presence as two sides of the same coin (Bauters et al., 2021). Moreover, we adopt the term *cues* rather than *signals*, following Feine et al. (2019), Wiltshire et al. (2014), and Zheng et al. (2023), who view cues as *antecedents* to social signals arising from the perceptible design features of a communication application. By contrast, signals stem from users’ conscious or subconscious interpretations of those cues, which, in turn, can elicit social reactions. This perspective aligns with the affordance framework discussed earlier: whereas cues primarily reflect a platform’s technological capabilities, signals and subsequent social responses depend on the user’s actual (and often implicit) interpretation and utilization of these cues. Furthermore, *cues* is suitable in the context of PAACs since they typically present a reduced or otherwise condensed information about awareness, minimizing the disruption of other concurrent tasks to be performed by users (Hudson & Smith, 1996). Although cues can be deliberately manipulated (Feaster, 2010), they frequently function outside direct user control or are generated automatically. Examples include time stamps, read receipts, or typing indicators in computer-mediated communication (Cobb et al., 2020b). Because these cues may inadvertently convey reliable information, Vinciarelli and Pentland (2015) have termed them “honest,” underscoring their potential to reveal a user’s status or intentions without conscious effort.

The literature on presence and awareness in CMC provides an almost infinite volume of examples of the social signals and reactions associated with PAACs. While we do not attempt to give a full systematic account of this broad literature, we still describe four selected dimensions of individuals’ use of PAACs to underscore their importance for human interactions in today’s CMC environment. For completeness, we also acknowledge the neuro-psychological perspective on mediated presence outlined by Riva et al. (2014), which emphasizes multisensory embodiment.

*Availability*, as indicated in our definition of PAACs, is central to initiating any form of communication (Begole et al., 2004). In the Global North, the ubiquity of smartphones and similar devices has enabled near-constant connectivity (Licoppe, 2004). However, individuals frequently negotiate their own availability by switching devices or apps on and off, enabling or disabling push notifications, or selectively revealing online status (Berlage & Sohlenkamp, 1999; Gutwin & Greenberg, 1998; Riemer et al., 2007; Schrock, 2015). These negotiations often depend on relational closeness: users typically allow a broader range of channels and higher availability for close ties, while limiting weaker connections to fewer channels and lower availability (Arnold et al., 2020; Haythornthwaite, 2005). In some cases, geolocation data, automatic tagging, or situational context can further refine these availability cues (Stone et al., 2008).

*Notifications* and *chronemic* cues play a critical role in shaping social signals derived from PAACs. The time that elapses between notification and response in asynchronous CMC functions as a key social indicator. Early work on email time stamps (Walther & Tidwell, 1995) as gradually evolved alongside new technological features. For example, read receipts were introduced in iMessage in 2010 and in Facebook Chat in 2012 (Hoyle et al., 2017; Lynden & Rasmussen, 2017). Combined with last-seen-online functionality, such read receipts can be interpreted as a deliberate non-reply if one interlocutor apparently had the opportunity to read the message (as shown by the last-seen time) but chose not to do so (as evidenced by the absence of a read receipt). This behavior can be perceived as offensive in personal communication (Kato & Kato, 2015). In organizational settings, “seeing another’s change of status (e.g. from ‘idle’ to ‘Reading Message’) may be enough to indicate that the other is engaged in team-related work and thereby heighten one’s willingness to work.” (Haines, 2021)

These cues already permit interlocutors to infer each other’s level of *attention*, yet many CMC applications include additional

features allowing users to signal their attentiveness explicitly. Perhaps the most common are reaction functions such as “likes,” applause icons, or emojis which provide direct, one-click feedback in both direct messaging and social networking platforms. Besides indicating attention, these reactions can serve as markers of social support, thereby strengthening interpersonal bonds (French & Bazarova, 2017).

Moreover, *effort* cues can critically shape how users perceive one another’s commitment in CMC. Typing indicators not only show that the other person is composing a message but can also reveal how long they have been doing so. The time spent typing, especially when compared against the eventual length of the message, may indicate the amount of effort invested and, by extension, the importance the sender attributes to both the message and the recipient (Karapanos et al., 2016; Kelly et al., 2017; Kelly et al., 2018; O’Hara et al., 2014).

**Content** differs markedly from PAACs in that it entails the deliberate sharing of text, voice, images, video, or other media, directed at an interlocutor, a chosen audience or, in the case of large social networks, potentially an unlimited public. Unlike largely automated PAACs, content typically relies on conscious user input (Karapanos et al., 2016; Madell & Muncer, 2007; Reid & Reid, 2004; Rettie, 2007) and is tailored to specific recipients (Arnold et al., 2020; Litt & Hargittai, 2016). This intentionality allows users to craft messages in accordance with their personal image or desired social norms, which can significantly shape how presence and identity are conveyed (Arnold & Schneider, 2017).

The third pillar, **aesthetics**, encompasses the configurable features that shape how individuals present themselves and perceive others in mediated settings, including filters, skins, avatars, or virtual outfits (Javornik et al., 2022; Liu, 2023; World Economic Forum, 2024; Yee & Bailenson, 2007). Such aesthetic affordances can strongly influence users’ subjective experiences and identity expression. They also create unique tensions with PAACs or content: for instance, an avatar signaling a specific gender or racial background may conflict with acoustic or textual cues (Freeman & Maloney, 2020; Maloney et al., 2020; Sykownik et al., 2022), potentially undermining the intended impression.

The fourth pillar, **fidelity**, concerns how effectively the other three pillars coalesce to produce what Skarbez et al. (2017) call place illusion and plausibility illusion (following Slater, 2009). In their words, “Slater make[s] it clear that we refer specifically and only to the strong illusion of being in a place and not to other multiple meanings that have since been attributed to the word ‘presence’”. Second, by introducing the concept of Plausibility Illusion and making it comparable in importance to Place Illusion, Slater reifies fidelity and correct behavior as important components of virtual experience.” To generalize this pillar beyond VR, AR, and MR settings, we introduce proximity illusion to describe simpler channels such as telephone calls or messaging apps.

While these four pillars collectively frame how users project and perceive presence, each pillar can be compromised or reshaped by external interventions or manipulations. For PAACs, many systems offer reciprocal settings. For instance, read receipts either show status information to all parties or to no one. Yet, some platforms permit one-sided blocking or “muting,” removing certain users from the perceiver’s environment unilaterally. Aesthetics choices can likewise be overridden if other users apply their own filters or skins without the original user’s knowledge (Bonner et al., 2023). Even content can be intercepted or altered (e.g., via deepfakes), although such modifications usually require more sophisticated, potentially malicious actions. Finally, fidelity often depends on network infrastructure and system performance; congestion, throttling, or deliberate disruption by external actors can degrade fidelity and undermine illusions of place, proximity, or plausibility.

#### 4. Development of research questions

As discussed above, a substantial yet fragmented body of work examines how awareness and presence take shape in CMC. However, most existing research remains narrowly focused on single platforms, contexts, or user cohorts (e.g. Church & de Oliveira, 2013; Gangneux, 2021; Mai et al., 2015; O’Hara et al., 2014). This specificity limits its value for policymakers and regulators, who require more generalizable insights to inform potential interventions. Our unified, technology-agnostic conceptualization of PAACs departs from this pattern: it clarifies core affordances and situates them among the broader building blocks of projecting and perceiving presence. In this section, we formulate research questions grounded in our PAAC framework, thereby filling the gap left by earlier research’s narrow scope.

Much of the existing research on PAACs has concentrated on how users interpret these cues as social signals (as presented in the preceding sections; for a review see e.g. Schrock, 2015). Implicit in most such studies is the assumption that users do notice these cues in the first place, yet empirical support for that assumption has been limited to a few isolated examples (e.g., Facebook Messenger read receipts in Hoyle et al., 2017). This brings us to our first research question:

RQ1: Do users notice PAACs in the apps and services that feature them?

This question extends beyond CMC-focused inquiries. As our conceptual framework suggests, PAACs increasingly appear in a range of digital settings, from collaborative productivity tools to entertainment platforms where “social presence” features may be less obvious (Cobb et al., 2020a). For instance, Twitch offers real-time indicators of who is watching or chatting (Hamilton et al., 2014), and Netflix-style “watch party” functionalities can display which friends are co-viewing and reacting (Løvlie et al., 2022). Audio streaming services have similarly introduced friend-activity feeds, effectively embedding PAACs into shared music experiences (Walsh, 2024). Despite these emerging use cases, many researchers remain focused on traditional social networking or direct messaging scenarios. With social network-like functionalities increasingly permeating audio/video streaming, gaming, and even educational platforms, our second research question examines whether user recognition of PAACs varies by application type:

RQ2: Does the share of users who notice PAACs differ based on the type of application in which these cues appear?

Whereas many PAACs, such as time stamps, read receipts, and typing indicators, are generated automatically, users often learn to circumvent or manipulate them albeit within constraints set by the application’s design. For instance, a common strategy involves

reading only the notification preview rather than fully opening the message, thus avoiding the “read” status that might signal availability or could lead to disappointment of others when an immediate response is impossible or unintended (Hoyle et al., 2017). Robert Lucky once envisioned a “presence dial,” enabling users to seamlessly control how much presence information they broadcast (Epstein & Moyers, 1990); however, most contemporary systems still offer only rudimentary on/off toggles, often buried in menus that can remain hidden affordances (Fox & McEwan, 2017). Previous studies on information control, primarily drawing on O’Sullivan (2000) and Feaster (2010), have tended to focus on narrow contexts. In contrast, our objective is to broaden the scope thereby enhancing its usefulness for policymakers as we examine the drivers behind how individuals manage PAACs for specific (1) contacts, (2) apps, (3) situations, and (4) locations. Accordingly, we formulate our third research question:

RQ3: How does contextual variability influence patterns of PAACs avoidance?

Building on Sykownik et al. (2022), who note that “disclosing personal information to others is one of the most important factors influencing the formation and maintenance of interpersonal relationships,” we propose that PAACs facilitate such disclosure. Existing studies show that users often derive personal insights from status messages or online indicators in a single messaging platform (Riemer et al., 2007). However, it remains unclear whether people consciously integrate these cues across multiple channels to build a more holistic picture of someone’s activities or whereabouts. As Haythornthwaite (2005) and Arnold et al. (2020) demonstrate, closer ties tend to use multiple communication channels, which may lead to richer personal disclosures (intentionally or not) through aggregated PAACs. While Effing (2024) highlights such a combination of data across platforms revealing personal patterns as a key ethical concern associated with the metaverse, to our knowledge, no prior work has examined this phenomenon systematically. We thus formulate our fourth research question:

RQ4: Do users who communicate through multiple CMC applications combine PAACs across platforms to form a more comprehensive understanding of each other’s routines and whereabouts?

Building on the concept of information control explored in RQ3, we also investigate whether knowing who else is actively online influences user behavior. Specifically, do individuals modify their actions or disclosures if they believe certain observers are monitoring their PAACs? Hence, our fifth research question is:

RQ5: Do users alter their own behavior when they know specific individuals are online and may observe their PAACs?

Although the precise contours of the metaverse remain unclear, any pervasive augmented reality (AR) will inevitably depend on collecting far greater volumes of personal data from applications and devices than is common in today’s CMC applications (McGill, 2021). These expanded data flows naturally feed into (novel) PAACs, likely revealing even richer dimensions of user activities and intensifying both the opportunities and risks related to PAACs. Consistent with our broader aim of conceptualizing and examining PAACs to identify emerging policy issues in metaverse contexts, we formulate the following sixth research question:

RQ6: Will individuals be inclined to share more information via PAACs in a metaverse environment, and conversely, expect others to disclose more information through PAACs as well?

Finally, we recognize that prior experience with AR or VR technologies could shape how users perceive and navigate PAACs. To capture such variations, we cluster our survey respondents based on their AR/VR familiarity, examining whether this factor influences the answers to RQ3 through RQ6. The next section details our sample and methodology, outlining how we investigate each question across different user groups.

## 5. Data and methodology

To investigate the research questions outlined in the previous section, we administered a computer-assisted web survey (CAWI) in China, Germany, France, Italy, the United Kingdom, and the United States. YouGov, a global market research firm, managed participant recruitment via consumer panels in each country. A total of 18,468 individuals completed the questionnaire. YouGov then applied its validated data-cleaning procedures, which flagged and removed 110 cases due to incomplete responses, inconsistencies, duplicate IP addresses, or unusual patterns (e.g., straight-lining). Consequently, the final dataset comprised 18,358 complete responses. Table 1 reports these respondents’ distributions by sex, age, and geographic region.

Data collection took place from April 26 to May 9, 2022. Rather than running a comprehensive pretest survey, we implemented a soft launch in collaboration with YouGov to identify potential technical issues or aberrant response behaviors. This preliminary stage did not reveal any major problems, although minor adjustments were made to the sequence of two questions. All responses gathered during the soft launch were excluded from the final sample.

YouGov’s sampling methodology applies quotas derived from demographic targets relevant to each country. Using a routing system, panel members who met the specified criteria were randomly assigned to this particular survey, rather than being invited to any single, stand-alone instrument. As a result, the response rate does not serve as a primary indicator of data quality, since sampling controls across multiple live surveys effectively ensured a representative cross-section of each country’s adult population.

Our survey, which followed an initial section on wearables and health applications, included items focused on respondents’ current use of online services (communications, social media, workplace, education, and streaming). Depending on which services they reported using, participants were asked if they noticed selected PAACs (e.g., online status, typing indicators) when they use the respective services. They also rated their agreement with statements about (a) avoiding or manipulating their own PAACs, (b) combining multiple PAACs to infer others’ routines, (c) modifying their behavior when certain contacts might see their PAACs, and (d) anticipating future expansion of PAACs in the metaverse and corresponding concerns referring to personal information disclosure. Answers were captured on seven-point Likert scales, with higher scores indicating stronger agreement or more frequent avoidance. In line with the overarching objective of the article to anticipate emerging challenges associated with the likely augmentation of PAACs, we grouped respondents by AR/VR familiarity (no use, past use, current use of at least one device) to elicit apparent differences in

**Table 1**  
Overview of the survey samples by country.

| China (n = 3007)          |         |   |         |
|---------------------------|---------|---|---------|
| <b>Sex</b>                |         | <b>Geographic area<sup>1</sup></b>                |         |
| Male                      | 56.00 % | North & North East                                | 28.10 % |
| Female                    | 44.00 % | East  | 16.30 % |
| <b>Age</b>                |         | South   | 21.60 % |
| 18–24                     | 25.00 % | Central   | 29.00 % |
| 25–34                     | 35.00 % | West  | 5.00 %  |
| 35–44                     | 23.00 % |   |         |
| 45–54                     | 11.00 % |   |         |
| 55+                       | 6.00 %  |   |         |
| <b>AR/VR familiarity</b>  |         |   |         |
| No use                    | 60.20 % |   |         |
| Past use                  | 29.30 % |   |         |
| Current use               | 10.50 % |   |         |
| France (n = 3078)         |         |   |         |
| <b>Sex</b>                |         | <b>Geographic area</b>                            |         |
| Male                      | 47.70 % | Nord-Est  | 23.40 % |
| Female                    | 52.30 % | Nord-Ouest  | 22.90 % |
| <b>Age</b>                |         | Region Parisienne                                 | 18.50 % |
| 18–24                     | 10.30 % | Sud-Est   | 24.40 % |
| 25–34                     | 15.20 % | Sud-Ouest   | 10.80 % |
| 35–44                     | 16.10 % |   |         |
| 45–54                     | 17.30 % |   |         |
| 55+                       | 41.10 % |   |         |
| <b>AR/VR familiarity</b>  |         |   |         |
| No use                    | 83.60 % |   |         |
| Past use                  | 13.20 % |   |         |
| Current use               | 3.22 %  |   |         |
| Germany (n = 3073)        |         |   |         |
| <b>Sex</b>                |         | <b>Geographic area</b>                            |         |
| Male                      | 48.62 % | Bremen, Hamburg, Lower Saxony, Schleswig-Holstein | 16.05 % |
| Female                    | 51.38 % | North Rhine-Westphalia                            | 21.62 % |
| <b>Age</b>                |         | Hesse, Rhineland-Palatinate, Saarland             | 13.66 % |
| 18–24                     | 9.15 %  | Baden-Wuerttemberg                                | 13.06 % |
| 25–34                     | 15.04 % | Bavaria   | 15.57 % |
| 35–44                     | 14.61 % | Berlin  | 4.30 %  |
| 45–54                     | 19.94 % | BB, Mecklenburg-Western Pomerania, Saxony-Anhalt  | 7.93 %  |
| 55+                       | 41.26 % | Saxony, Thuringia                                 | 7.81 %  |
| <b>AR/VR familiarity</b>  |         |   |         |
| No use                    | 80.30 % |   |         |
| Past use                  | 15.10 % |   |         |
| Current use               | 4.56 %  |   |         |
| Italy (n = 3065)          |         |   |         |
| <b>Sex</b>                |         | <b>Geographic area</b>                            |         |
| Male                      | 47.60 % | North West  | 26.60 % |
| Female                    | 52.40 % | North East  | 19.20 % |
| <b>Age</b>                |         | Centre  | 19.80 % |
| 18–24                     | 8.10 %  | South   | 23.30 % |
| 25–34                     | 13.40 % | Islands   | 11.10 % |
| 35–44                     | 17.20 % |   |         |
| 45–54                     | 19.50 % |   |         |
| 55+                       | 41.80 % |   |         |
| <b>AR/VR familiarity</b>  |         |   |         |
| No use                    | 82.00 % |   |         |
| Past use                  | 14.00 % |   |         |
| Current use               | 4.05 %  |   |         |
| United Kingdom (n = 3052) |         |   |         |
| <b>Sex</b>                |         | <b>Geographic area</b>                            |         |
| Male                      | 48.52 % | North   | 23.30 % |
| Female                    | 51.48 % | Midlands  | 16.10 % |
| <b>Age</b>                |         | East & South                                      | 31.60 % |
| 18–24                     | 10.78 % | London  | 13.10 % |
| 25–34                     | 15.17 % | Wales   | 4.80 %  |
| 35–44                     | 18.64 % | Scotland  | 8.40 %  |
| 45–54                     | 14.45 % | Northern Ireland                                  | 2.70 %  |

(continued on next page)

Table 1 (continued)

| Italy (n = 3065)         |         |                        |         |
|--------------------------|---------|------------------------|---------|
| 55+                      | 40.96 % |                        |         |
| <b>AR/VR familiarity</b> |         |                        |         |
| No use                   | 83.70 % |                        |         |
| Past use                 | 13.40 % |                        |         |
| Current use              | 2.92 %  |                        |         |
| United States (n = 3083) |         |                        |         |
| <b>Sex</b>               |         | <b>Geographic area</b> |         |
| Male                     | 49.60 % | Northeast              | 20.00 % |
| Female                   | 50.40 % | Midwest                | 21.90 % |
| <b>Age<sup>b</sup></b>   |         | South                  | 36.60 % |
| 18–24                    | 13.75 % | West                   | 21.50 % |
| 25–34                    | 19.79 % |                        |         |
| 35–44                    | 18.39 % |                        |         |
| 45–54                    | 20.82 % |                        |         |
| 55+                      | 27.25 % |                        |         |
| <b>AR/VR familiarity</b> |         |                        |         |
| No use                   | 72.30 % |                        |         |
| Past use                 | 19.10 % |                        |         |
| Current use              | 8.56 %  |                        |         |

<sup>a</sup> by city tier: Tier 1 (17.0 %); Tier 2 (38.0 %); Tier 3 (45.0 %). The sample was drawn to represent the online population in China and therefore differs from the samples in the other countries.

<sup>b</sup> the US sample differs from other country samples in that there is a survey cut-off at 75 years of age.

projecting and perceiving presence in mediated environments. As Table 1 indicates, China shows the highest AR/VR familiarity in our dataset: 10.5 % of respondents report current use of at least one device, 29.3 % have used a device in the past, and 60.2 % have no prior experience. The US posts a similar share of current users (8.6 %), whereas the United Kingdom and France trail behind (~3 % current and ~13 % past users). Although truly comparable market statistics do not exist to the best of our knowledge, the relative ranking aligns with the most recent Statista (2023) AR/VR market report, which likewise places China ahead of the United States and Europe.

Two caveats merit explicit attention. First, by design a CAWI approach excludes the offline population estimated at 17 % in urban China, 13 % in France and Italy, and about 5 % in Germany, the United Kingdom, and the United States (ITU, 2025). Individuals without internet access typically exhibit lower digital literacy and minimal exposure to immersive hardware; their omission therefore inflates the observed prevalence of AR/VR familiarity. Second, participation in online panels is correlated with higher tech-savviness (Redmiles et al., 2019), which can further bias upward any indicator linked to emerging technologies. While national quota controls help align the sample demographically, the absolute percentages of AR/VR experience reported here should be read as upper-bound estimates rather than as population parameters.

Our categorization draws primarily on AR/VR familiarity, we however acknowledge that the metaverse encompasses a far broader spectrum of platforms and environments than AR/VR alone. These may range from avatar-based virtual worlds and game-based ecosystems (Dionisio et al., 2013) over collaborative workspaces and mobile AR overlays to complex multi-modal embodiment technologies (Lee et al., 2024; Park & Kim, 2022). Our reliance on AR/VR usage as an indicator thus glosses over some of the nuance in these diverse metaverse modalities. Nonetheless, it captures the essential question of whether a respondent has had any meaningful “touchpoints” with immersive technologies, in particular those involving specialized hardware and whether such usage is current. This distinction implies not only ongoing engagement but also, in all likelihood, a more proficient exploration of metaverse-related applications and interfaces.

Across the six countries, the median completion time varied between 21 and 24 min. This is longer than the optimal range of 10–15 min for online panel surveys, but still within the 20- to 28-min window recommended by Revilla and Höhne (2020). Meanwhile, completion rates spanned from 78.4 % in the United Kingdom to 91.3 % in China, aligning with the ~85 % average completion rate that Liu and Wronski (2018) reported on a larger dataset of 25,000 online surveys. Similarly, Callegaro and DiSogra (2008) recorded a completion rate of 84.5 % under comparable conditions. Once the fieldwork concluded, all responses were downloaded in a comma-separated format for analysis using R. To test for statistically significant differences referring to the selected grouping variables, we used Kruskal-Wallis tests, and wherever relevant post-hoc Dunn tests with Bonferroni corrections corresponding to the non-parametric nature of the data collected. The results of these tests are documented under each table in detail.

In the subsequent section, we present aggregated results for each research question to identify the broad policy implications of PAAC use. Rather than delving into cultural distinctions or individual applications with marginal effects, we cluster our findings by three major regions (1) China, (2) Europe, and (3) the United States. While individual country-level are available on request, we prioritize a higher-level synthesis to guide policy interventions.

## 6. Results

This section presents our findings for each of the six research questions (RQ1–RQ6) developed earlier. While we note differences across three regional clusters – China, Europe, and the United States – our primary emphasis is on overall trends in awareness and

information control associated with PAACs, along with the role of AR/VR familiarity in shaping user responses. We intentionally reserved detailed cross-cultural comparisons for future research. Nonetheless, it is important to acknowledge existing evidence from cross-cultural survey research indicating that respondents in China exhibit distinct response styles when answering Likert-scale items. Specifically, prior studies have shown that Chinese respondents frequently adopt a midpoint or acquiescent response style, resulting in systematically higher average agreement scores compared to Western counterparts (Guo & Spina, 2019; Harzing, 2006). This response tendency is particularly pronounced in China's tier-1 cities (Magdolen et al., 2024), which constitute a substantial portion of our Chinese sample. Consequently, the comparatively elevated absolute scores observed for the Chinese respondents in the following results may partly reflect these culturally rooted response patterns rather than substantive attitudinal differences alone. Importantly, however, the principal relationships explored in this study referring to the differences associated with AR/VR familiarity remain consistent and comparable across all three regional clusters.

**RQ1 & RQ2 – Recognizing PAACs in Different Applications:** Table 2 indicates that a clear majority of users notice PAACs when using applications with prominent communication or coordination functions. For instance, in communications-oriented services, 93 % of respondents in China, 90 % in Europe, and 86 % in the US report observing at least some form of PAAC. Social media and workplace tools similarly rank high (75–91 % across all regions). Multiplayer games, often reliant on real-time collaboration, also prompt substantial recognition of PAACs, particularly in China (89 %) and the US (82 %).

Educational applications, which may offer fewer opportunities for or even no interactions at all, register a pronounced decline in PAAC awareness, most notably in Europe (56 %) and the US (62 %). By contrast, 80 % of educational-app users in China still report noticing PAACs, hinting at variations in how these tools are designed or adopted. Streaming services, where social features are ancillary to content consumption, show the lowest PAAC recognition rates: 35 % in Europe, 36 % in the US, and 76 % in China.

In summary, these data suggest that users are more likely to notice PAACs in apps that emphasize direct social exchanges. Regional differences persist, but the overarching theme is that frequent or integrated communication features tend to increase PAAC visibility.

**RQ3 – Avoiding or Withholding PAACs:** We next examined how individuals manage personal information disclosure through “switching off, circumventing, or otherwise avoiding” PAACs. Table 3 provides mean scores on a seven-point scale, disaggregated by region, contexts, and AR/VR familiarity.

Across all three regions, avoidance ranges from moderate to high (4.2–4.8 considering the region means). Current AR/VR users consistently report greater avoidance, regardless of whether the inquiry concerns specific contacts, apps, situations, or locations. On average, the difference between no use and current use of AR/VR amounts to .55 points for China, .5 for Europe, and even .7 points for the US. All of these differences are statistically significant (Kruskal-Wallis test  $p < .01$ ).

Significance tests reveal modest regional distinctions in how respondents prioritize different contexts for withholding PAACs. In China, avoiding PAACs for certain contacts ranks slightly higher than for apps, situations, or locations. In the US, location emerges as a particularly important factor. Meanwhile, in Europe, apps appear least associated with avoidance, whereas contacts, situations, and locations all show higher avoidance scores. Overall, these findings underscore that individuals tailor their PAAC information disclosure according to social and situational context rather than relying on a blanket on/off approach in a specific application or service.

**RQ4 – Combining PAACs Across Multiple Platforms:** Table 4 examines whether users combine PAACs from different platforms to gain a more comprehensive picture of others' routines. Overall mean agreement on a 1–7 scale is highest in China (4.6), moderate in the US (3.6), and lower in Europe (3.1). AR/VR familiarity again plays a role. In China, current AR/VR users average 5.2, compared with 4.4 among non-users. In Europe (2.9) and the US (3.2), non-users average below the midpoint, while current users exceed it (4.4 and 5.0 respectively). These results suggest that Chinese respondents in general and AR/VR users across regions are notably more inclined to piece together PAACs from various sources.

**RQ5 – Altering One's Own Behavior When Others Are Online:** Given that some users combine PAACs to map others' whereabouts, a natural follow-up question is whether individuals adjust their own behavior upon realizing specific contacts are online. Table 5 shows a similar pattern to RQ4. China records the highest overall mean (4.7), followed by the US (3.5) and Europe (3.3). Once again, AR/VR users register stronger agreement, especially in China (5.2) and in the US (4.9). In Europe, non-users average 3.2, whereas current AR/VR users reach 4.4. These figures underscore that heightened sensitivity to real-time presence learned in AR/VR environments is associated with corresponding changes in one's information control as regards disclosures of PAACs.

**Table 2**

Results for research questions (RQ1 and RQ2).

| Category of services/applications | Share of respondents noticing PAACs (in %) |        |    |
|-----------------------------------|--|--------|----|
|                                   | China                                      | Europe | US |
|                                   | Communications                             | 93     | 90 |
| Social media                      | 91   | 83     | 80 |
| Workplace applications            | 91   | 76     | 75 |
| Multiplayer games                 | 89   | 70     | 82 |
| Education applications            | 80   | 56     | 62 |
| Streaming services                | 76   | 35     | 36 |

n (China) = 3007; n (Europe – FR, DE, IT, UK) = 12,268; n (US) = 3083; in percent rounded. These results are meant to be purely descriptive. Correspondingly, no tests for statistical significance were conducted.

**Table 3**  
Results for research question 3 (RQ3).

| RQ3: How does contextual variability influence patterns of PAACs avoidance?                                       |                                       |      |      |      |            |      |      |      |            |      |      |      |
|---|---------------------------------------|------|------|------|------------|------|------|------|------------|------|------|------|
| PAACs avoidance by AR/VR familiarity  | Likert-Scale Value (Min = 1, Max = 7) |      |      |      |            |      |      |      |            |      |      |      |
|   | China                                 |      |      |      | Europe     |      |      |      | US         |      |      |      |
| <b>For specific apps</b>  | <b>4.7</b>                            |      |      |      | <b>4.2</b> |      |      |      | <b>4.6</b> |      |      |      |
| No use  | 4.6                                   |      |      |      | 4.1        |      |      |      | 4.5        |      |      |      |
| Past use  | 4.8                                   |      |      |      | 4.4        |      |      |      | 4.8        |      |      |      |
| Current use   | 5.2                                   |      |      |      | 4.7        |      |      |      | 5.2        |      |      |      |
| <b>For specific contacts</b>  | <b>4.8</b>                            |      |      |      | <b>4.3</b> |      |      |      | <b>4.6</b> |      |      |      |
| No use  | 4.6                                   |      |      |      | 4.3        |      |      |      | 4.5        |      |      |      |
| Past use  | 4.9                                   |      |      |      | 4.5        |      |      |      | 4.8        |      |      |      |
| Current use   | 5.2                                   |      |      |      | 4.8        |      |      |      | 5.2        |      |      |      |
| <b>For specific locations</b>   | <b>4.7</b>                            |      |      |      | <b>4.4</b> |      |      |      | <b>4.8</b> |      |      |      |
| No use  | 4.6                                   |      |      |      | 4.3        |      |      |      | 4.7        |      |      |      |
| Past use  | 4.8                                   |      |      |      | 4.5        |      |      |      | 4.8        |      |      |      |
| Current use   | 5.1                                   |      |      |      | 4.8        |      |      |      | 5.3        |      |      |      |
| <b>For specific situations</b>  | <b>4.7</b>                            |      |      |      | <b>4.4</b> |      |      |      | <b>4.7</b> |      |      |      |
| No use  | 4.6                                   |      |      |      | 4.3        |      |      |      | 4.5        |      |      |      |
| Past use  | 4.8                                   |      |      |      | 4.5        |      |      |      | 4.8        |      |      |      |
| Current use   | 5.1                                   |      |      |      | 4.7        |      |      |      | 5.3        |      |      |      |
| Contrasts for categories in each region (Kruskal-Wallis test with post-hoc Dunn test with Bonferroni correction)* |                                       |      |      |      |            |      |      |      |            |      |      |      |
| Categories  | China                                 |      |      |      | Europe     |      |      |      | US         |      |      |      |
|   | A                                     | C    | L    | S    | A          | C    | L    | S    | A          | C    | L    | S    |
| Apps (A)  |                                       | n.s. | n.s. | n.s. |            | ***  | ***  | ***  |            | n.s. | *    | n.s. |
| Contacts (C)  | n.s.                                  |      | n.s. | *    | ***        |      | n.s. | n.s. | n.s.       |      | **   | n.s. |
| Locations (L)   | n.s.                                  | n.s. |      |      | ***        | n.s. |      | *    | **         |      |      | n.s. |
| Situations (S)  | n.s.                                  | *    | n.s. |      | ***        | n.s. | n.s. |      | n.s.       | n.s. | n.s. |      |

Average score of respondents' stated behavior as regards switching off, circumventing, or otherwise avoiding to signal their presence or awareness for selected (1) situations, (2) contacts, (3) locations, and (4) apps in the respective service category on the digital services they stated to have used in the four weeks prior to the survey (the list featured (1) communications, (2) social media, (3) workplace applications, (4) multiplayer games, (5) education, and (6) streaming); Min = 1; Max = 7, n (China) = 2574; n (Europe – FR, DE, IT, UK) = 7902; n (US) = 2015; Kruskal-Wallis test followed by a Dunn post-hoc test with Bonferroni correction:  $p < .01$  for all within region/country differences except Europe (for specific apps: past use/current use  $p < .05$ , for specific contacts: past use/current use n.s., for specific locations: past use/current use n.s., for specific situations: past use/current use n.s.), US (for specific apps: no use/past use n.s., for specific locations: no use/past use n.s.; corresponding effect sizes: For specific apps: China: .0272 (small), Europe: .00591 (small), US: .0112 (small); for specific contacts: China: .0184 (small), Europe: .00433 (small), US: .0169 (small); for specific locations: China: .018 (small), Europe: .00385 (small), US: .00675 (small); for specific situations: China: .02 (small), Europe: .00316 (small), US: .0167 (small). \*Additional information: China: Kruskal-Wallis test:  $p < .05$ ; effect size: .000633 (small); Europe: Kruskal-Wallis test:  $p < .01$ ; effect size: .00111 (small); US: Kruskal-Wallis test:  $p < .01$ ; effect size: .0013 (small).

**Table 4**  
Results for research question 4 (RQ4).

| RQ4: Do users who communicate through multiple CMC applications combine PAACs across platforms to form a more comprehensive understanding of each other's routines and whereabouts? |                                       |        |     |
|---|---------------------------------------|--------|-----|
| Combining PAACs across multiple platforms by AR/VR familiarity  | Likert-Scale Value (Min = 1, Max = 7) |        |     |
|   | China                                 | Europe | US  |
| Mean (all)  | 4.6                                   | 3.1    | 3.6 |
| No use  | 4.4                                   | 2.9    | 3.2 |
| Past use  | 4.8                                   | 3.6    | 4.0 |
| Current use   | 5.2                                   | 4.4    | 5.0 |

Average agreement with the statement "For contacts with whom I am connected across several online services and apps, I get a good sense of their whereabouts and routines by combining the information I learn about them in each individual service or app" 1 = "Strongly disagree", 7 = "Strongly agree". n (China) = 3007; n (Europe – FR, DE, IT, UK) = 12,268; n (US) = 3083; Kruskal-Wallis test followed by a Dunn post-hoc test with Bonferroni correction:  $p < .01$  for all within region/country differences; corresponding Kruskal-Wallis effect sizes: China: .0377 (small), Europe: .0339 (small), US: .0796 (moderate), rounded. AR/VR familiarity refers to respondents who no, former, and current use of AR/VR devices (at least one).

**RQ6 – Expanding PAACs in a Metaverse Context:** Finally, **Table 6** summarizes attitudes toward expanded or more detailed PAACs in a future metaverse. Users already familiar with AR/VR report higher willingness (mean 4.7–5.3 in China, 4.3–4.8 in Europe, 4.6–5.4 in the US) to broadcast or receive additional cues, yet they also anticipate stricter disclosure limits enacted by themselves and others. AR/VR non-users in Europe and the US show comparatively low enthusiasm (2.6–3.2) for sharing more cues, though they still register moderate expectations (4.3–5.2) about becoming more restrictive. Overall, these results imply that those more accustomed to immersive technologies feel both more open to novel PAACs and more mindful of the disclosure trade-offs they entail.

**Table 5**  
Results for research question 5 (RQ5).

| RQ5: Do users alter their own behavior when they know specific individuals are online and may observe their PAACs? |                                       |        |     |
|--|---------------------------------------|--------|-----|
| Altering one's own behavior when others are online by AR/VR familiarity  | Likert-Scale Value (Min = 1, Max = 7) |        |     |
|  | China                                 | Europe | US  |
| Mean (all)   | 4.7                                   | 3.3    | 3.5 |
| No use   | 4.5                                   | 3.2    | 3.1 |
| Past use   | 4.8                                   | 3.8    | 4.2 |
| Current use  | 5.2                                   | 4.4    | 4.9 |

Average agreement with the statement "I alter my behavior based on the information I received about other users who I am aware are online at the same time as I am." 1 = "Strongly disagree", 7 = "Strongly agree". n (China) = 3.007; n (Europe – FR, DE, IT, UK) = 12,268; n (US) = 3083; Kruskal-Wallis test followed by a Dunn post-hoc test with Bonferroni correction:  $p < .01$  for all within region/country differences; corresponding Kruskal-Wallis effect sizes: China: .0312 (small), Europe: .0265 (small), US: .0868 (moderate), rounded. AR/VR familiarity refers to respondents who no, former, and current use of AR/VR devices (at least one).

**Table 6**  
Results for research question 6 (RQ6).

| RQ6: Will individuals be inclined to share more information via PAACs in a metaverse environment, and conversely, expect others to disclose more information through PAACs as well? |                                       |            |            |
|---|---------------------------------------|------------|------------|
| Attitudes towards future PAACs scenarios by AR/VR familiarity   | Likert-Scale Value (Min = 1. Max = 7) |            |            |
|   | China                                 | Europe     | US         |
| <b>Broadcast greater variety of PAACs about me (a)</b>  | <b>4.7</b>                            | <b>3.0</b> | <b>3.6</b> |
| No use  | 4.3                                   | 2.6        | 2,7        |
| Past use  | 4.6                                   | 3.3        | 3,9        |
| Current use   | 5.2                                   | 4.3        | 5,0        |
| <b>Broadcast more specific PAACs about me (b)</b>   | <b>4.5</b>                            | <b>2.8</b> | <b>3.2</b> |
| No use  | 4.3                                   | 2.6        | 2,8        |
| Past use  | 4.6                                   | 3.3        | 3,9        |
| Current use   | 5.1                                   | 4.4        | 4,9        |
| <b>Expect myself to become more restrictive on PAACs (c)</b>  | <b>4.7</b>                            | <b>4.7</b> | <b>5.2</b> |
| No use  | 4.4                                   | 4.7        | 5,2        |
| Past use  | 4.9                                   | 4.8        | 5,2        |
| Current use   | 5.3                                   | 4.9        | 5,5        |
| <b>Receive greater variety of PAACs about others (d)</b>  | <b>4.7</b>                            | <b>3.1</b> | <b>3.6</b> |
| No use  | 4.5                                   | 2.9        | 3,1        |
| Past use  | 4.9                                   | 3.6        | 4,3        |
| Current use   | 5.3                                   | 4.4        | 5,1        |
| <b>Receive more specific PAACs about others (e)</b>   | <b>4.7</b>                            | <b>3.1</b> | <b>3.6</b> |
| No use  | 4.5                                   | 2.9        | 3,2        |
| Past use  | 4.8                                   | 3.6        | 4,3        |
| Current use   | 5.2                                   | 4.5        | 5,1        |
| <b>Expect others to become more restrictive on PAACs (f)</b>  | <b>4.7</b>                            | <b>4.4</b> | <b>4.9</b> |
| No use  | 4.5                                   | 4.3        | 4,8        |
| Past use  | 4.8                                   | 4.6        | 5,0        |
| Current use   | 5.3                                   | 4.8        | 5,4        |

Average agreement on a Likert-like scale ranging from 1 = "Strongly disagree" to 7 = "Strongly agree" for the statements: (1) "I would welcome a greater variety of cues available about [others'/my] current availability, awareness, and actions.", (2) "I would welcome new cues that provide [me/others] with more specific information about [others'/my] current availability, awareness, and actions.", and (3) "I would expect [others/myself] to become more restrictive in sharing information about [their/my] current availability, awareness, and actions.", n (China) = 3.007; n (Europe – FR, DE, IT, UK) = 12,268; n (US) = 3083; Kruskal-Wallis test followed by a Dunn post-hoc test with Bonferroni correction:  $p < .01$  for all within region/country differences except for Europe (for (c) Kruskal-Wallis test overall n.s., (f) former use/current use is n.s.), US (for (c) Kruskal-Wallis test overall  $p = .025$  with only former use/current use reaching  $p = .0198$  and the other contrasts being n.s., (f) no use/former use is n.s.), corresponding Kruskal-Wallis effect sizes: for (a): China: .0364 (small), Europe: .0404 (small), US: .121 (moderate); (b): China: .0303 (small), Europe: .0379 (small), US: .107 (moderate); (c): China: .0431 (small), Europe: not applicable because Kruskal-Wallis test n.s., US: .107 (moderate); (d): China: .0377 (small), Europe: .0339 (small), US: .0796 (moderate); (e): China: .0307 (small), Europe: .0369 (small), US: .102 (moderate); (f): China: .0356 (small), Europe: .00406 (small), US: .006 (small); rounded. AR/VR familiarity refers to respondents who no, former, and current use of AR/VR devices (at least one).

Taken together, the survey results confirm that participants generally recognize and manage PAACs in ways attuned to specific social contexts, technologies, and, in particular, AR/VR familiarity. The following section draws on these findings to explore policy implications and evaluate the evolving debate around personal information disclosure control in metaverse environments.

## 7. Discussion

This article has advanced a unified conceptualization of how individuals project and perceive presence in mediated environments, offering policymakers and regulators a technology-agnostic vocabulary to shape potential interventions in the metaverse. It also investigated six research questions specifically centered on PAACs (the first pillar), examining user perceptions and behaviors in contemporary CMC, alongside an initial sense of how these might evolve if PAACs expand in a metaverse. The following discussion situates these insights in the existing literature, highlights practical considerations in light of ongoing technological and market shifts in AR/VR, and lays the groundwork for future research priorities and policy recommendations.

Recent attention has turned toward generative AI, sidelining some of the hype around the metaverse. Yet despite setbacks in AR/VR (e.g., Magic Leap, Microsoft HoloLens), other ventures signal continuing progress. The Meta-Ray-Ban smart glasses surpassed one million units sold in 2024, with a projected goal of five million by 2025 (Roth & Heath, 2025). Although dwarfed by the 1.22 billion smartphones sold in 2024 (Canalys, 2025), these wearables embody a trend toward unobtrusive, AI-driven “expert systems” reminiscent of what O’Hagan et al. (2023) describe. As such devices mature, metaverse platforms may increasingly “instrument the actions, attitudes, and emotions not just of the wearer, but of all those within their sight or within the sensing range of their equipment and its networks” (McGill, 2021).

These developments prompt a look at the four pillars introduced in Section 3 to understand how an emerging metaverse could reshape presence and awareness. Aesthetics (pillar 3) and fidelity (pillar 4) appear poised for remarkable advances. They can facilitate tailored realities that may be essential for tasks like establishing spatial convergence in virtual collaborative work (Wong et al., 2024) or enhancing accessibility for visually impaired individuals. At the same time, this capacity to individualize experiences risks fragmenting social consensus through politicized filters (O’Hagan et al., 2023) and might enable unsolicited filters that users apply to others without consent (Bonner et al., 2023). While content (pillar 2) will not undergo the same degree of transformation, the way users engage with or interpret it may shift under these immersive affordances. The greatest impact, however, concerns PAACs (pillar 1), as the apparent convergence of “physiological, affective, and social computing research agendas” (Moge et al., 2022) stands to incorporate biosignals ranging from heart rate to electroencephalogram (EEG) to infer emotional or cognitive states (Lux et al., 2018). In doing so, they would move well beyond current features facilitating contact discovery, availability negotiation, and attention signaling in CMC.

Recent HCI studies illustrate how such expansions might unfold. These include fatigue indicators, conversational parity visualizers, frisson detection, and gaze-based nudging (Bektaş et al., 2024; Huang et al., 2024; Jing et al., 2024; McVeigh-Schultz & Isbister, 2021). One in-depth study showed that although participants deemed biosignal display appealing, they were unsure how to manage or limit the disclosure of personal data (Lee et al., 2022). This tension evokes early visions of a “presence dial” (Epstein & Moyers, 1990), underscoring the allure of “making VR more real” through nuanced PAACs, even as users worry about who might gain access to them.

Our six-country survey indicates that PAACs already occupy a central position in current CMC practices. Applications that rely on coordination or real-time communication, such as messaging services, commonly integrate these cues. Around 90 % of users notice them, echoing similarly high awareness rates of online status indicators (Cobb et al., 2020b).

Three further insights emerged from the survey consistently for the three observed regions. First, those who engage with PAACs are willing to invest time and effort to piece together cues from multiple applications in a keen interest of gleaning deeper social signals about others. Second, the same users frequently enact measures to control their personal information such as refraining from opening messages or toggling status settings and thus keep certain cues private. Third, respondents with AR/VR exposure, who have at least some experience with novel ways of rendering PAACs (Osborne et al., 2023; Tanenbaum et al., 2020), appear especially alert to these cues and deliberate about self-presentation.

Information control parallels observations in recent metaverse-focused research. Bauters et al. (2021) note similar concerns around systems that track physiological states, especially when emerging sensors and opaque data-collection methods can undermine user autonomy (Hadan et al., 2024). Even seemingly profane user inputs such as keystroke patterns may reveal personal attributes including a user’s sex (Buker et al., 2019). Given the “stickiness” of digital user data (Fox & McEwan, 2017), future metaverse PAACs can exceed the privacy risks associated with early surveillance-based workplace telepresence systems discarded for their intrusive nature (Begole et al., 2002; Hudson & Smith, 1996; Nunes et al., 2007).

Our survey participants were somewhat ambiguous in their attitudes towards a metaverse mainstreaming new cues. On the one hand, their feedback suggests enthusiasm for richer social signals and the immersive interactions these signals enable; on the other hand, it highlights apprehension about losing control over personal data. This tension reflects contradictory attitudes: many users want more expressive tools but also fear that advanced cues could make privacy harder to manage. Although a fully realized metaverse may still lie ahead, its essential building blocks including sensor technology, data-handling algorithms, and keen user interest are already in place. The key challenge is not whether these augmented cues will surface, but how they will be deployed and with what safeguards.

Metaverse designers will have to make further efforts to refine interfaces for both usability and user autonomy. Legislators may also need to determine if current policies are sufficient for regulating biosignal-driven cues that produce (possibly) unintended disclosures. At present, PAACs remain largely absent from mainstream policy discussions, despite repeated calls to examine the ethical and privacy ramifications of real-time sensing (Cobb et al., 2020b; McStay, 2023). Achieving consensus on where to draw the line with potential “surveillant physics” (McStay, 2023) necessitates broader societal dialogue about how comprehensively we wish to monitor or share biometric states.

Policymakers globally struggle to find the sweet spot between intuitive interaction, which mirrors everyday face-to-face cues, and robust consumer protection. A brief comparison of the three jurisdictions covered by our survey illustrates how different value systems translate into distinct regulatory paths towards a comprehensive framework for metaverse governance.

In the European Union, the AI Act exemplifies this tension. By listing facial recognition and emotion inference as banned or high-risk applications, the regulation safeguards mental privacy. At the same time, its broad wording could make it difficult to build simple, user-friendly interfaces that rely on subtle PAACs such as gaze matching or mood badges. Without design guidance or exemptions, the risk is that useful presence cues become technically or legally impracticable, which in turn could slow metaverse adoption.

The California Consumer Privacy Act (CCPA), as amended by the California Privacy Rights Act (CPRA), shows why design choices and governance tools such as an intuitive “presence dial” are indispensable for user-centric implementation of PAACs. Biosignal-rich PAACs, for example heart-rate traces or focus scores, are classified here by default as sensitive personal information. That protection, however, vanishes once a user streams those cues to a public lobby or an interoperable feed. Given current social-media habits, such voluntary sharing is plausible. Data that a consumer “lawfully makes available to the general public” are treated as publicly available information and fall outside the statute’s protective umbrella. A single toggle can therefore turn a cool biosignal overlay for an avatar into fresh advertising fuel.

Beijing has promoted metaverse infrastructure since at least 2016 (Gray & Tang, 2025). The government’s 2023–2025 metaverse roadmap (元宇宙产业创新发展三年行动计划) champions advanced biometric interactions ranging from eye-tracking to emotion recognition to drive immersion. Two guardrails moderate this ambition. First, the Personal Information Protection Law (PIPL) treats biometric data as sensitive personal information for private actors, imposing strict purpose limitation and consent. Second, the 2025 CAC Regulation on Facial Recognition (人脸识别技术应用安全管理办法) forbids making biometric cues mandatory for access and demands opt-in consent plus on-screen labels when they are used. In practice a metaverse platform in China can implement gaze indicators or mood avatars only on a voluntary and transparent basis, with most data processed locally or on state-vetted servers. Compliance has become a design requirement: meeting these rules builds user trust and aligns with national priorities, while missteps could see a flagship feature declared unlawful.

Augmented PAACs could equally generate positive developments, such as new opportunities to monetize personal data skipping current gatekeepers (Pandjaitan et al., 2024) or improve interactions for deaf or visually impaired individuals. Additional cues might also serve as building blocks for consent mechanisms in virtual or augmented worlds, as proposed in Zytka and Chan (2023), thereby paving the way for safer social interactions. Balancing these benefits against the ethical dilemmas they pose underscores the importance of legislative guardrails and explicit user-consent frameworks.

Through our four-pillar model, it is evident that a metaverse populated with rich, largely automated PAACs will not simply replicate current communication norms but may radically alter them. Determining the degree and direction of that alteration calls for sustained collaboration among researchers, application providers, policymakers, and users. By recognizing PAACs as critical to the user experience in immersive contexts, and by fostering transparent policy dialogues about privacy, consent, and design, future metaverse ecosystems could deliver more meaningful social presence while mitigating risks of intrusive or manipulative data use.

## 8. Conclusion and recommendations

In the near future, the ways individuals project and perceive presence in pervasive AR/VR environments will not only shape experiences in virtual realms, but also redefine everyday F2F encounters enriched by biosignals and other complex PAACs. Safeguarding consumers in this continuously mediated environment requires policies that prevent harm yet still enable intuitive interfaces and tools, fostering more meaningful rather than confusing user experiences.

Our four-pillar model - covering PAACs, content, aesthetics, and fidelity - presents a technology-agnostic framework for understanding how presence is co-constructed and perceived in computer-mediated contexts. By offering policymakers a comprehensive vocabulary for potential interventions grounded in a broad review of the current literature, it helps illuminate how different configurations of presence emerge. Findings from the six-country survey indicate that the vast majority of users notice PAACs across various online services, adapt to them dynamically, and engage in deliberate information control. Integrating these results with recent HCI work on biosignal-driven PAACs brings to light substantial gaps in current policy debates.

Our conclusions constitute a call to action for policymakers, developers, and researchers. Rather than imposing blanket rules that risk generating cumbersome user interfaces, interventions must be guided by empirical evidence on actual consumer behavior. Such an approach would balance necessary protective guardrails with design freedom in metaverse systems. A potential outcome of consumer-based research could be standardized, user-friendly “dashboards” for managing PAACs. These would acknowledge the likely interoperable nature of the metaverse and the nuanced ways users tailor information disclosure by contact, location, or situation rather than relying on scattered, application-specific toggles buried in different menus. Notably, this recommendation is broadly aligned with the international push towards personal information management systems (PIMS) manifested in ISO/IEC 27701:2019. It provides concrete technical guidance on the implementation of such systems, combining key notions of the European GDPR, CCPA/CPRA, and the Chinese PIPL reflecting the three regions covered by our survey.

At the same time, regional trajectories diverge: the European Union leans toward precaution, California banks on user self-disclosure, and China fuses industrial acceleration with state-defined guardrails. Designers therefore need more than one global template; PAAC controls must be built as modular layers that can be tuned to local law while preserving a coherent user experience. In practice, elements like a presence dial, local processing defaults, or mandatory cue labelling should be engineered so they can be tightened, relaxed, or re-purposed depending on whether a service operates under the AI Act, the CCPA/CPRA, or the PIPL combined with CAC facial-recognition rules.

Achieving a workable balance among privacy, user control, and interface simplicity in the metaverse is no small task. Gaze tracking illustrates the complexity. While it is crucial to certain immersive experiences, it can also reveal sensitive personal traits from attention patterns to sexual orientation. Legislators therefore face the challenge of placing real-time sensing practices like location, gaze, and

biosignals within effective privacy and consent frameworks, without undermining beneficial uses. The AI Act, for example, may unintentionally restrict intuitive PAACs that could otherwise replicate the natural, F2F cues we already navigate confidently, hindering fluid and consumer-friendly implementations of advanced PAACs.

## 9. Limitations and future research

Our survey relied on CAWI panels, inevitably skewing the sample toward tech-savvy individuals; the familiarity and comfort with PAACs reported here should therefore be read as upper-bound estimates. A second constraint is our proxy for “metaverse familiarity.” We classified respondents by AR/VR-device use, a pragmatic marker of immersion, yet one that excludes rich forms of non-headset participation, e.g., persistent game worlds or browser-based virtual communities. Broader engagement metrics (time in social VR, avatar-mediated work, mobile AR overlays) would capture the metaverse’s heterogeneity and test whether distinct participation patterns map onto different PAAC attitudes.

Cultural context further limits generalization. Although quota sampling yielded nationally representative cells referring to age, sex, and regions across six countries, we pooled results at a world-regional level, postponing fine-grained cross-national comparisons. Future studies should pair psychometric harmonization with qualitative work to uncover how local etiquette, for example, norms of reply speed or visibility of biosignals, shapes PAAC acceptance, thereby guiding regulators toward culturally calibrated safeguards.

Empirically, survey methods must now be complemented by in-situ work. Field experiments in social VR or AR can reveal how users negotiate advanced cues such as real-time gaze or heart-rate indicators when fully immersed. Longitudinal deployments will track whether early discomfort attenuates as communities normalize new signals, echoing historical trajectories observed for “read receipts” in mobile messaging.

A second agenda concerns interoperability and identity management. As the EU’s Digital Markets Act pushes cross-platform messaging and eventually interoperable social networks, scholars should examine unified dashboards that display and let users edit PAACs spanning multiple avatars or services. Research questions include whether users prefer one consolidated presence across contexts or compartmentalized signals that mirror their role boundaries (professional vs. recreational).

A second, still-unresolved facet of interoperability is robust identity assurance across virtual worlds. Duplicate, fake and sybil accounts already erode trust on today’s platforms, prompting metaverse-ethics scholars to call for authentication schemes that are simultaneously verifiable and privacy-preserving (Al-Kfairy et al., 2025; Effing, 2024). Building on our findings, we propose exploring PAACs as a lightweight cross-world authentication layer. Physiological traces that AR/VR devices already capture including gaze vectors, heart-rate variability, gait patterns could help verify that the same human stands behind an avatar as it moves between spaces, deterring sybil attacks and identity spoofing. Yet the richer cues that would enable this “PAAC-auth” approach also heighten the cross-platform profiling risks our survey brought to light. Any interoperable PAAC-auth scheme must therefore secure provenance without dismantling the contextual privacy boundaries users actively negotiate.

Design research is equally critical. Our data show users already manage simple cues strategically; forthcoming, higher-bandwidth signals risk overload. Prototypes of PAACs control panels could be iteratively tested for usability and trust. The work by Cho et al. (2025) could be a starting point for such an undertaking. Work on social biofeedback underscores that presentation style (color, animation, granularity) alters how observers interpret physiological data; HCI studies should therefore identify visualization principles that minimize misinterpretation.

## CRedit authorship contribution statement

**René Arnold:** Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anna Schneider:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization.

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