AmbiDots: An Ambient Interface to Mediate Casual Social Settings through Peripheral Interaction

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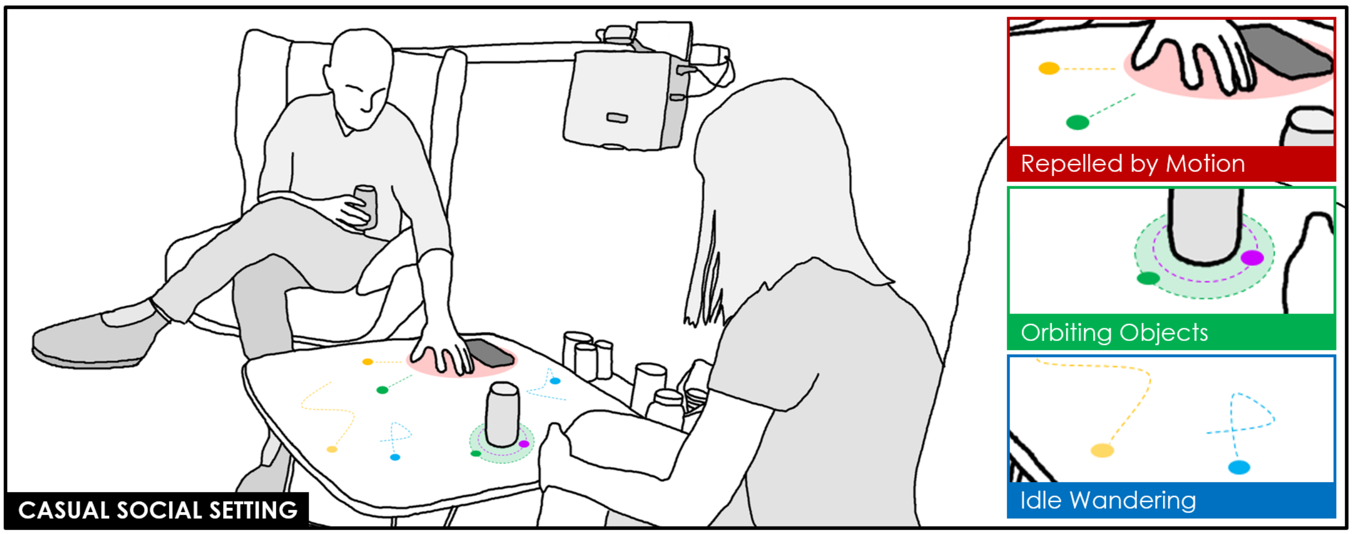

Figure 1: AmbiDots uses subtle, coloured dots to support peripheral playful interactions in public social and shared settings like cafes, restaurants or bars.

ABSTRACT

Ambient systems leverage mediums such as colour, shape, form, and motion to convey meaningful representations of information in the periphery of the user. This allows users to attend to several streams of information outside of their central attention without invoking additional cognitive load. While previous work explored how this paradigm might enable the user to take on a greater load of practical information, comparatively little work explored the potential this holds to mediate *casual social interactions*. In this paper, we examine how playful and abstract ambient interfaces leverage ambiguity and curiosity to create unobtrusive peripheral interactions that mediate and facilitate social interactions. We discuss the design and implementation of **AmbiDots**, an ambiguity-centric ambient system that uses subtle, coloured dots to support peripheral playful interactions in social settings like cafes, restaurants or bars. Our study demonstrates how this system enables various forms of social appropriation without disrupting social interaction.

CCS CONCEPTS

• **Human-centered computing** → **HCI**.

KEYWORDS

Ambient Interfaces, Peripheral Interaction, Social Casual Settings, Design for Ambiguity

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1 INTRODUCTION

Interactive technology can be a powerful way of connecting people in public spaces [16]. Public systems and interfaces often use new forms of interactivity, such as interactive wall displays, physical computing, projection mapping, or augmented reality, to affect the way groups or individuals interact with their direct environment, (e.g., interactive walls [42], public data installations [29], art environments [38] or museum installations [28]), but also enable new forms of human-to-human experiences [7, 10]. Most technologies supporting such public interventions into '*third spaces*' [43] are aimed at attention-grabbing short burst of activities or interactions that form or shape in-situ experiences connecting people, interactivity and environments [12, 50]. The main experimentation grounds for such systems have been traditionally in public spaces, streets, museums, office environments, or public parks.

However, most of these interventions and technological explorations are designed as attention-grabbing media that are meant as active mediators between people and places to construct dynamic and new experiences [50]. In contrast, many *third-places* such as bars, restaurants, lounges or cafes are environments where such attention-grabbing interfaces are less relevant and important [37]. Rather, such social settings are exemplar for places where people focus on human-human interaction in a calm, relaxed and often informal setting [64]. People like to ponder and discuss the many (food or drink) options with their company, simply for the pleasure of open-ended conversation — not concerned with practical goals [55]. In the same way, time spent in a cafe is often focused on chatting and socialising with friends and family. Such places are used by many to *escape* time, to remove oneself from their work-lives to *reconnect* with our environment and those around us. While such intimate, calm and relaxed places play a fundamental role in people's lives, there is surprisingly little work that explores the role of technology as a mediator of such personal casual social settings.

In this work, we explore how to design playful ambient systems that mediate conversation and social interactions in calm and relaxed social settings such as cafes, bars, and restaurants. The goal of our approach is to explore non-attention grabbing, yet interesting and playful interactions that facilitate and augment relaxed human-to-human social interactions. Prior work in the space of ambient interfaces and peripheral interactions have explored non-attention grabbing interfaces — but these focus predominantly on communicating data or information [4, 30, 52]. Due to the considerable focus of previous works on practical applications, this area of ambient system design remains unexplored. As such, there is little empirical evidence demonstrating this potential of Ambient Systems in supporting our casual values in practice; let alone practical guidance on how one might design and evaluate such systems in the absence of usability metrics. We propose that there are substantial open challenges around what the right mediating role is for such ambient systems, how interactivity can be embedded and integrated into such casual social settings, but most importantly: how such a systems can be appropriated and integrated into human-human social interactions.

In this paper, we present **AmbiDots** — an ambient system designed specifically for casual social settings, such as cafes, bars, and restaurants. We begin by synthesizing the relevant literature from this field into our own 7 design principles. From here, we describe the specifics of our implementation; followed by a breakdown of our user study — used to gather insights into the affective impacts of our principled design in practice. We describe our findings in terms of user feedback, quantitative use patterns, and observations of user behaviour, before discussing the implications of our findings for the development of future systems for casual social settings.

2 BACKGROUND

This work touches upon many different topics and domains, such as public displays, social interaction, affective computing or ambient and peripheral systems. While a full review of these domains is beyond the scope of this paper, we discuss below selected work from those domain that bind together the central argument of our paper: *to use ambient ambiguity to design for casual social places.*

2.1 Ambient or Peripheral Systems

Calm Computing refers to Weiser's vision of Ubiquitous Computing (UbiComp) technologies [62] which reside comfortably in our periphery, enabling the user to control where their attention is placed. Rogers later refined and contextualised these ideas against the reality of the real world, re-framing calm computing as "*engaging UbiComp experiences*" [49]. Pousman and Stasko described [47] how systems built in adherence to this vision have varied greatly. They point to examples that present little information in an abstract way, with an emphasis on being aesthetically pleasing; and other systems that focus on presenting several information streams, with an emphasis on information accuracy and user awareness [47]. Some of the earliest examples of ambient systems, *AmbientROOM*, operationalized this in the form of water shadows, light projections, and subtle sounds that are combined to enable users to be more aware of activity outside the reach of their central attention [63].

From their earliest instances, studies of ambient systems have predominantly taken an *output-focused* approach; i.e. with little to no interactivity [26, 34, 47, 63]. Recognising this, Bakker et al. highlights the relevance of exploring *peripheral interaction* — that is — the capacity for systems to support interaction without central focus [4], much in the same way we might drink from a cup without conscious thought of the action. Matthies expands on this concept, describing the potential for systems to support *Reflexive interaction* — defined as a manifestation of peripheral interaction that focuses on unobtrusive, nonchalant interactions, executed with minimal cognitive effort required [35]. There are many concrete examples of the applications of peripheral interaction technology including *physical visualisations* [51, 52], *notification devices* [61], floor displays [59], *art installations* [38] or setups for *collaborative work* [53, 56]. More recent work, such as Physikit [30] or Olly [41], also explored how interactive ambient peripheral devices can be used with *slowness* or *configured feedforward* as a way to convey information in everyday situations.

Prior work has also focused on exploring *casual information visualizations* that depict and embed data in everyday life [48], in the design of public ambient information visualization [54] or in wider contexts or situations [6]. An example of this, by Hinrichs et al., explored information visualisation in casual settings – in their case a museum [27]. Furthermore, in the space of physical data representations, many examples focus on representing data in 'everyday' social settings. Examples include urban situated visualisation [32] or public data installations [29]. This approach of casual information visualization for non-expert users has been echoed outside academia in the *Data Humanism* approach by Lupi [33].

Looking at applications of Ambient Systems in the current literature, it is clear that the '*information transmission*' use case holds a strong dominance. This is perhaps highlighted best by Pousman and Stasko's examination of 19 distinct ambient systems which are all examples designed to transmit purposeful information in varying degrees [47]. Pousman and Stasko themselves even opt for the name "*Ambient -**Information**- Systems*" to refer to the entire sub-domain. This paints a clear picture that alternative usage of the ambient system form factor is currently under-explored. Recent studies, such as the work by Balaam et al. [5] and Dimicco et al. [19], demonstrate that peripheral ambient displays can implicitly and subtly influence social interactions. These views have recently also been widened into trying to understand the role of *interactive architecture* [21] or even *human-building interaction* [2]. However, there are many open questions around how to design and evaluate *subtle interaction* [46]. Furthermore, to avoid creating direct and demanding feedback mechanisms, implicit systems might benefit from new perspectives at designing interaction that, for example, consider approaches such as *slow-motion feedback* [60].

2.2 Curiosity and Affect

While the concept of *affective interfaces* [45] encompasses a broad array of HCI and psychology research, our specific interests concern systems designed to elicit emotion experiences from users [36], as opposed to productive ends. Christensen is one of many to assert the current landscape of HCI to be overly usability-oriented - alerting to the danger of interaction becoming "*tedious and instrumental*" [9]. Rather than maximising predictability and functionality as a blanket rule — he foresees potential for UIs across several application contexts to instead maximise concepts like ambiguity and personality; rewarding excess rather than seeking to diminish it. Gaver et al. [22] expands on the use of ambiguity as a design resource — describing its potential to elicit intrigue, mystery, and delight in the user. This potential is seldom tapped however, due to the frequent and long standing villianisation of ambiguity from the traditional, usability-centric mindset [22]. Furthermore, Tieben et al explores using curiosity to mediate behaviour (for which he describes ambiguity to play a pivotal role) [57]. They cite a prime example of this in action - TheFunTheory's Piano Stairs [44]. Here, an interactive piano staircase designed to appear and behave as piano keys is deployed in public. By invoking curiosity in passers-by, the stairs enticed 66% more individuals to opt for the stairs as their means of escalation over the functionally superior escalator. A reflection on literature focusing on '*playful interactions*' [17, 39, 40] or '*affective experiences*' [11, 14] demonstrates that simple casual mechanisms can be a powerful motivator for shared social public interaction.

Finally, our research takes great inspiration from Heider and Simmel's classic (1940s) study of apparent behaviour [25]. Their study presented participants with simple shapes (dots and triangles), moving in a fashion which alluded to a sort of ambiguous narrative. On subsequently being asked to describe what they saw, participants effortlessly unpacked rich, complex, emotionally-oriented explanations from the very simple, but subtly suggestive, stimuli they had just witnessed. Their findings demonstrate the incredible creative capacity humans have to devise rich, imaginative narratives from minimal prompts when we perceive these prompts to exhibit a level of agency. We speculate that the principles underpinning this kind of stimuli can, through research like AmbiDots, be refined into a set of design principles that helps digital technology appropriately integrate with our casual social worlds.

3 AMBIDOTS

AmbiDots (Figure 1) is an ambient system designed for casual social spaces such as cafes, bars, and restaurants. Using a visual language of ambiguously behaving coloured dots, AmbiDots presents playful, peripheral, interactive, and dynamic interfaces that respond to motion and objects. Similar visual languages have been proven useful, due to their pleasant aesthetic simplicity, in recent literature [3] as well as commercial systems [1]. AmbiDots mediates and embraces social interaction within these spaces by empowering the user to retain presence in their environment, rather than become distracted from it. AmbiDots uses a custom-built Projection Vision System (PVS) to support interfaces on arbitrary flat surfaces (like tables, bars, or walls) in the social space, thus, providing an ambient layer of "*digital decoration*" [24] over the shared interaction space.

3.1 Designing for Social Spaces

Technology that is embedded in social spaces such as cafes, bars, and restaurants has different design characteristics than traditional goal-oriented interfaces. Such social spaces afford different types of social interactions that are often dynamic, opportunistic, playful, relaxing, or simply experiential [20]. In these environments, people value relaxing and socialising with those they are with, rather than achieving productive ends. As such, interactions with technology should be sporadic, peripheral, and mostly aimed at facilitating the social interaction. Information or aesthetic displays within social spaces should appear *simple and require low or short bursts of attention* as complex, visually stimulating systems would be distracting and thereby less suitable for social settings. Within these environments, a balance is needed between providing interesting, conversational prompting stimuli, whilst not distracting those present should they wish to direct their focus elsewhere, such as their conversation. Similarly, *ambient sound* is common in social spaces, but a balance is needed between uncomfortably quiet and distractingly noisy. Lastly, *darker lighting* is employed in social spaces to foster a relaxing atmosphere - compared to work spaces where brighter lights are used for engagement and focus.

3.2 Design Principles of AmbiDots

Although prior work has established taxonomies [47] and design recommendations [23] for Ambient Systems, these exclusively refer to systems designed for practical ends like information transmission and work-collaboration. There are currently no clear established design principles for affect-orient ambient systems — where use cases are not planned, but rather appear naturally and freely — which we argue would be much better suited for social spaces. The central goal of AmbiDots is to mediate and support pleasant experience and social interaction through an ambient interface which allows for open ended, peripheral interaction in an unobtrusive, playful, and transparent way. We thereby synthesise previous work on designing for peripheral interaction [4], curiosity [57], ambiguity [22], and others (see 'Background' section) into a set of 7 principles used to guide the design of AmbiDots:

D1 — **Ambiguity**: Ambiguity in system design has shown potential to elicit intrigue and delight [22]. Furthermore, it has been identified as a major player in enticing curiosity and thereby encouraging system exploration [57]. Lastly, ambiguity is key in enabling interpretability - allowing users to devise rich narratives to make sense of the stimuli [25].

D2 — **Ambience**: We assert that the ability to place central attention on either those around us or our own thoughts is a necessity of casual, social settings. As such, we believe the core principle of ambient systems, to comfortably reside in the periphery, to be essential for our system context [4].

D3 — **Unobtrusiveness**: Unlike the many ambient systems which feature notification elements (such as [8, 58]), for casual social settings, we propose the ability to retain uninterrupted presence within our environment and those around us is of utmost importance in retaining our humanity and serenity [49, 62].

D4 — **Subtle Interactivity**: Where ambiguity might entice users to take a 'first step' into system exploration, the reward of a reaction might encourage subsequent acts of further exploration [31]. A sudden, precise response however may unintentionally grab the user's attention. As such, employing subtlety may work towards balancing exploration reward with over-stimulation.

D5 — **Clear Inconsequentiality**: The fear that interacting with the system might entail consequences (as is the case for traditional, task-oriented interfaces) that make users much more hesitant to explore without central attention placed on the system. An understanding that one's action are inconsequential avoids the 'fear of mistake', allowing the user to feel comfortable casually interacting, even in the periphery [4].

D6 — **Apparent Agency**: Interacting with a perceived agent is naturally more interesting than a perceived procedural system. Enabling users to interpret system behaviour in intelligent terms rather than mechanical may intrigue the users to a greater extent, and encourage their formulation of narratives [25].

D7 — **Socially-Conducive Positioning**: The interaction space ought to be positioned so that socialising is supported, not hindered. Interaction should encourage users to face towards their peer(s), and be easy and natural to access in terms of both reach and gaze. This ensures users are able to unconsciously attend to the system's behaviour in their periphery, minimising effort (and attention) required to interact [62].

We note that these 7 principles are likely not exhaustive and apply a narrowing scope to potentially broadening factors such as group size and physical scale. Our intention is to specify a framework, drawn from related work, that enables us to reason about the different aspects of AmbiDots.

3.3 Formative Workshops

To guide the design of AmbiDots, formative feedback was gathered by presenting a non-interactive AmbiDots prototype to individual participants in a quick, low-fidelity workshop format. The goal of these workshops was to observe how participants reacted to the system, and gather insights into how our visualisation was interpreted, what events participants expect the visualisations to react to, and what they believed this reaction would look like.

3.3.1 Context. Workshops were set up in a controlled laboratory environment. Availability sampling was used to gather 8 participants, all of whom were students across a range of subjects and levels of study; ages distributed within the range 18-28. A projector was mounted above a desk to stage the visualisation. Lighting in the room was dimmed to make the projection clear and prominent.

3.3.2 Procedure. Participants took part in the workshop individually. To avoid biasing the results, we did not describe the experiment or system before the workshop. We instead outlined the procedure of the trial to participants and assured them that any and all questions would be answered after the workshop. After providing their written consent to continue, participants were presented with a non-interactive AmbiDots visualisation, with the dots switching every couple minutes or so between 'idle wandering' (Figure 1) and orbiting around arbitrary points. Throughout the workshop, we conducted a semi-structured interview with open-ended questions on how the participant would respond to and interact with the visualisation using, touch input, objects (such as a glass), and by mimicking the motion of dots.

3.3.3 Findings. Our findings allowed us to assess how our current design was meeting our design criteria, and were used to inform further development towards the final design. The stand-out findings which allowed us to refine our system were as follows:

- **Finding 1:** The most common ways participants expected to interact with the system was using their hands.
- **Finding 2:** The most common interaction-expectations were for dots to be 'attracted' to objects and 'repelled' by motions.
- **Finding 3:** Participants on the whole did not believe they would naturally intuitively think to try mimicking the movement of dots, nor was there a common expectation on how this would influence behaviour of the dots.
- **Finding 4:** Participants interpreted the nature of the dots across a variety of metaphors. The range of dot-descriptions included the terms "ants", "fish", "pond animals", "natural", "organic", "flying", "bouncing balls", "magnets", and "stars".
- **Finding 5:** Seeing all dots exhibiting the exact same behaviour, e.g., all orbiting the same arbitrary point and the same speed, lead many to perceive the dots as pre-programmed and procedural rather than agent driven.

3.4 AmbiDots Interface

The AmbiDots Interface is made up of several interactive, ambiguously behaving, firefly-like dots projected onto a flat surface - inspiring the system's name: ***AmbiDots***. The default behaviour of the dots is to idly wander around the space. Dots react to motions or objects detected in the space by changing their movement behaviour.

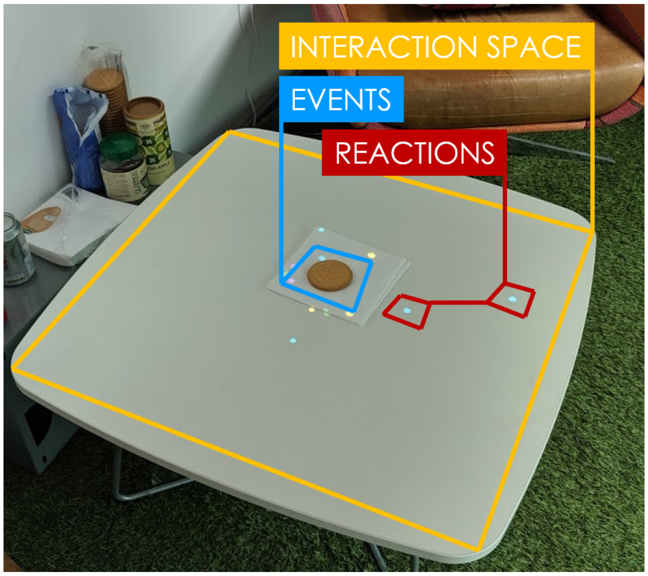

Figure 2: The three main components of AmbiDots are the interaction space, the events, and the reactions.

For example, placing a glass on the table would cause nearby dots to slowly approach and begin circling around the glass - as if exploring the object. A quick wave of a hand would cause nearby dots to dart away, as if scared away. To support this style of interaction, the AmbiDots system (Figure 2) is composed of three main components: (i) *the interaction space* - the tracked and projected area, (ii) *events*, or inputs, caused by the users or any objects in the space, and (iii) *reactions*, which are behavioural changes in response to events.

3.4.1 Interaction Space. The interaction space is the physical space or surface where input and output occurs. In this space, events (motions and objects) are detected, and reactions (changes in dot-behaviour) take place. The interaction space is characterised by the presence of the dots themselves. Finer details of dot-behaviour within the space were guided by our design principles.

Following D6, we designed dots to imply a level of agency in the way they move and react, rather than appearing as procedural, and unintelligent. To achieve this, we programmed dots to always move by orbiting around a point. This caused their movements to appear more elliptical, and thereby less programmatic than movement in straight lines. When engaged with an object, we programmed dots to traverse its circumference at a given distance. When 'idly wandering', a dot's orbital point and speed are ever changing (within a specified range) - constantly jumping small distances in arbitrary directions. The result is a circular, seemingly organic movement, much like the movement of flies.

In consideration of D3, we took measures to ensure the system's output was not too stimulating or attention demanding. We limited the total number of dots to <15 (such that they appeared sparsely rather than in large swarms); limited their speed to a slow, subtle pace; and ensured they moved smoothly and continuously. The pre-established aesthetic simplicity of the small dots also aided this design principle. Further details regarding the behaviour of dots, specifically in relation to 'Events' (generated through interaction) are described in the 'Reactions' subsection below.

3.4.2 Events. We designed AmbiDots to recognise two event types: *objects* and *motions*. We define *objects* as static entities within the interaction space; and *motions* as moving entities within the interaction space, or any entities intersecting the edge of the space, e.g., a static hand. These event-types were chosen due to their natural occurrence in the target setting, allowing the user to more easily discover the system's interactivity. More involved events such as 'mimicking' dots (TraceMatch [13]) were omitted based on our workshop findings (#3), due to people being unlikely to naturally discover or perform these in the periphery. Additionally, since tangible objects and movement are ways in which we naturally interact with the physical world, recognising and responding to these allowed us to make the system appear more unified with the physical world — keeping the users present within it, rather than distracting them from it.

We used Computer Vision (CV) to achieve this event recognition. Connected to a camera mounted above the interaction space, our CV component checked each frame for instances of objects and motions. This is performed by first isolating the region-of-interest and converting the frame to grey-scale to remove redundant data and applying a Gaussian blur to reduce noise. Background subtraction is then used to produce two foreground masks — one by comparing with a pre-established background frame to isolate objects, the other by comparing with immediately preceding frames to isolate motions. The object-detection process is visualised in Figure 3 and 4. Where a recognised object is touching the edge of the interaction space, the detection is instead labelled as a motion, since we did not want dots to attempt orbit if blocked by an edge. Although this component functions fully automatically, as a contingency for our study, we also implemented real-time manual correction functionality, i.e. 'Wizard-of-Oz' [15] overlay controls. Left-click-drags on the preview window are programmed to be registered as an object detection in the region drawn. Right-click-drags are registered as an update to the background frame - nullifying any detection.

3.4.3 Reactions. AmbiDots was designed to react to instances of events by altering the behaviour of the dots. By default, dots move away from motions, and slowly move towards and orbit around objects when detected. We primarily based this behaviour on feedback from our workshops, which revealed a common expectation among participants for dots to be attracted to objects and repelled by motions. This behaviour was intended to mirror intelligent, animalistic behaviour of 'running away' from motions (i.e. things which appear threatening) and 'exploring' of objects (i.e. things which are idle and thereby non-threatening). Our workshop findings (#1 and #2) revealed these reactions to be in line with natural expectations.

Beyond this base functionality, additional features were implemented to enrich system reactivity further. For instance: if dots occluded with a motion for a given period of time, i.e. they could not 'run away' fast enough, we designed them to timeout and be replaced by a new dot, entering from the edge of the interaction space. To the user, this would appear as the dot shrinking into nothingness, followed by a new dot spawning in. The rate at which a new dot could be spawned was capped to avoid a sudden flurry of new dots

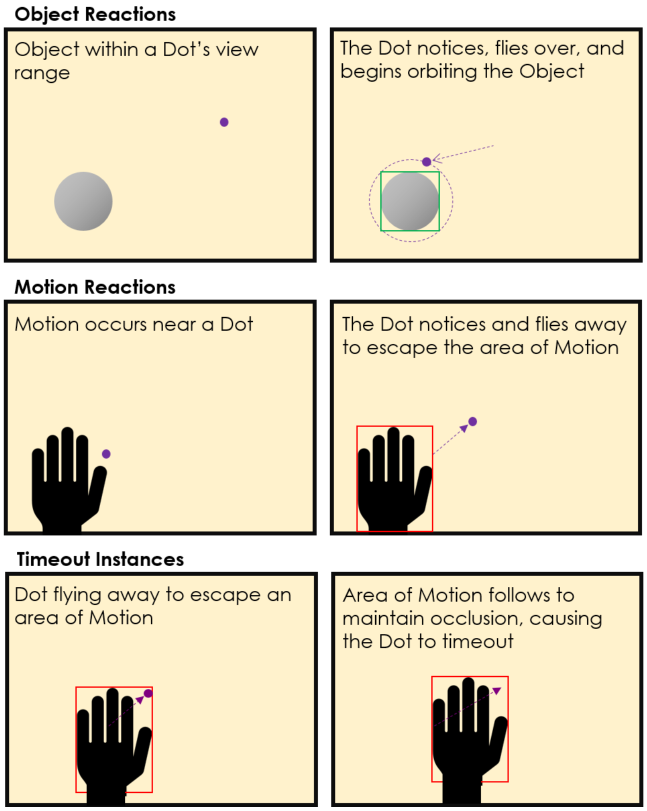

Figure 3: Reactions to objects, motions, and timeout.

making the system too attention grabbing. In response to our workshop finding (#5) that all dots exhibiting the exact same behaviour was not in line with D6, we developed 'personality profiles' and assigned one to each dot. This controlled finer points of the dot's behaviour, including its speed, rate of direction change, and color. We also included 'flags' within each profile which would cause dots to exhibit non-default behaviour, such as ignoring objects, ignoring motions, or even being repelled by objects.

More specifically, we use personality profiles to dictate the upper and lower bounds for a number of each dot's character-defining variables, including: The speed a dot moves; its colour range; the distance it orbits an object from; the maximum distance it can see an object from; the rate it jumps between orbit-points when 'wandering'; the maximum distance of an orbit-point jump; any flags enabling any non-default behaviour. For example, a profile might specify a speed range between 0.2 - 0.4 pixel distance per frame. The speed of any dots created with this profile would be bounded by these values. For our study, 4 personality profiles were used, each with unique characteristics, and made distinguishable by colour:

- **Purple Dots** - *Excited*: Fast; very frequent but very small jumps; avoids motions.
- **Yellow Dots** - *Curious*: Moderate speed; infrequent but very large jumps; avoids motions.
- **Cyan Dots** - *Shy*: Slow; small but fairly frequent jumps; very quick timeout; avoids objects as well as motions.
- **Green Dots** - *Normal*: Moderate speed, jump frequency, and distance; avoids motions.

A standard principle of usability-centric system design is to minimise response time to avoid user confusion and maximise task efficiency. Given that 'efficiency' is not a criteria to be maximised for our system design, we decided to explore moving away from this principle. In line with D4 and D6, rather than clear and instantaneous event-responsivity (which would make dot-behaviour to appear entirely directed) we designed dots to react faster or slower depending on their speed (determined by their personality profile), as well as their proximity to the event itself. Our intention was for this to convey a level of agency in the dots. This design characteristic also fed into the ambiguity (D1) of the visualisation as a whole by allowing users to question whether dots were reacting to their actions, rather than having the answer presented immediately and clearly — leaving no room for curiosity and exploration.

3.5 Implementation

We implemented the AmbiDots system as two key sub-systems. The first for detecting input within the interaction space using Computer Vision (CV), the second for visualising output to be projected onto the interaction space. Using a publish-subscribe method, the CV component sends live object and motion data to the visualisation component to, in turn, determine the dots reactions. We used a 5-tuple format to transmit object and motion data from the CV component (Figure 4). This contained: a label denoting the event 'type', the starting x and y-coordinate value of the event and the width and height of the event.

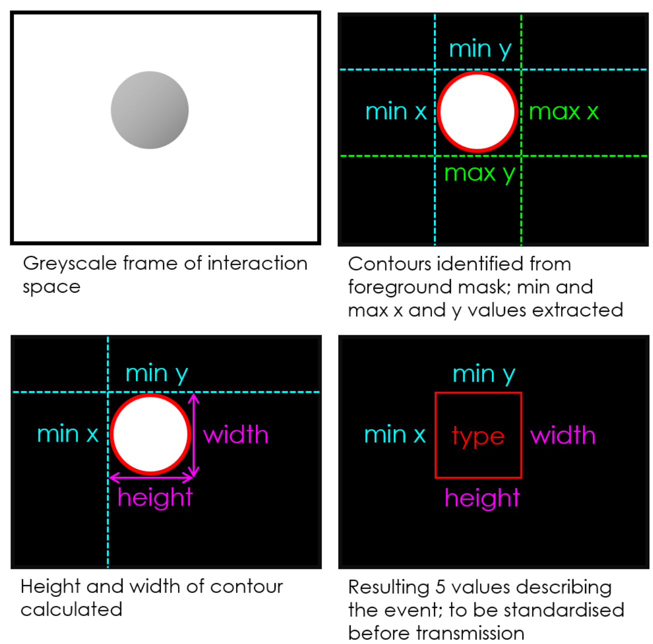

Figure 4: Process for the detection and object data.

4 STUDY DESIGN AND METHODOLOGY

We conducted an exploratory user study to reveal insights into the affect that ambiguous ambient systems have on users in casual social settings. Our study observations were general and open-ended, and reflect on factors such as: *mood*, *behaviour*, and *general social interactions*.

4.1 Environment

We set up a controlled, pseudo-social study environment in a semi-public shared office building. We chose a space away from people walking past, but where the ambient noise of other people was still audible. This was to strike a balance between establishing control over environmental variables, whilst also maximising ecological validity, i.e. resemblance to a genuine social setting (specifically a cafe, coffee shop, or networking space). We deployed a collection of furniture to further support ecological validity. This included lounge chairs, pillows, a coffee table, a plant, artificial grass flooring, and refreshments. Additionally, a black sheet was used to maintain greater control over lighting, to avoid this interfering with the CV component (Figure 5).

Figure 5: Study Environment in a 'pseudo' public setting.

4.2 Apparatus

The apparatus allowed the projector and camera, driven by the visualisation and CV component, to be mounted discreetly above the interaction space. Power and data cables were secured to the same aluminium profile which held the hardware in place. We constructed this apparatus in line with our design principle of *unobtrusiveness*, striving to minimise it's noticeability, and reinforcing the illusion that the dots are part of the physical environment.

4.3 Participants

We used availability sampling to recruit 22 participants. Due to the setting, most participants were SME employees. 12 participants were between the ages of 18 - 28, the remainder 10 between 29 - 55. 13 participants identified as male (59%), the remaining 9 as female (41%). As the study was designed to simulate a real life social setting, and thereby foster genuine social interaction, participants were paired by familiarity with each other. Of the 11 pairs, 9 were familiar colleagues, but 2 sets were unacquainted before the study.

4.4 Procedure

Before each trial, participant pairs were briefed. This informed them that the trial would last around 10-12 minutes, that it would be recorded, and that it would be followed by a short questionnaire and interview. We asked participants to treat their time in the trial as if it were a genuine social setting, like a coffee shop. In pursuit of natural reactions we intentionally described as little as possible about the AmbiDots system itself. Participants were assured that nothing in the trial was designed to make them uncomfortable in any way, and guaranteed a debriefing to address any questions following the trial. During each trial, we left the trial area, leaving participants to socialise naturally. After a 10-12 minute period, we would conclude the trial and immediately ushered participants into separate rooms to complete a questionnaire. Following this, we brought participants back together for a reflection and debrief. We conducted a recorded unstructured interview alongside this to gain deeper insights into their interpretations of, and reactions to, their experience with AmbiDots.

ID	Statement
S1	I **enjoyed** the presence of the system
S2	I found the time **more enjoyable** with the system present than had it not been
S3	I found the system **annoying** or distracting
S4	I was **curious** about the purpose of the system
S5	I found the system **intriguing**
S6	I found the system **uninteresting**
S7	I found the system **fun** to interact with
S8	I found the system **awkward** to interact with
S9	I would find the system **off-putting** in a social space e.g. a bar or coffee shop
S10	I **would interact** with the system if I came across it in a social space
S11	The system made interacting with my peer **easier**
S12	The system **hindered** me from interacting with my peer

Figure 6: All 12 Likert statements used in our study.

4.5 Data Collection and Analysis

Our data collection methods included a questionnaire and unstructured interview. The questionnaire comprised 12 Likert statements and 8 open-ended questions. We phrased the questionnaire to lead the participants as little as possible. For example, we used the term "shapes" to describe the dots, and "system" to describe AmbiDots under the rationale that these were the most general way we could refer to them. The Likert statements (Figure 6) used a combination of positive and negative phrasing to minimise acquiescence bias and increase reliability by repeating statements in different formats (e.g. S5 — *"I found the system intriguing"* and S6 – *"I found the system uninteresting"*). We also randomised their order for each participant to avoid ordering bias. We analysed our Likert responses by calculating each statement's median, as well as by visualising response frequencies as a stacked bar chart (Figure 7). We analysed both the open-ended questions and interviews through thematic analysis. This allowed us to identify common themes across responses in a quantitative format (Figure 8).

Video and audio of the trials were recorded using a GoPro camera device mounted in the corner of the study environment. Our choice of recording device and placement was designed to be discrete so as to minimise participants awareness of it. To quantify this data effectively, we developed a bespoke application, allowing us to efficiently timestamp instances of specific re-occurring events at a high precision — including postural changes, object placement within the interaction space, and periods of system engagement. This provided us a higher level, quantitative overview of participant behaviour and system use patterns. For our analysis, we define periods of "system engagement" as where the participant's gaze is fixated on the system, or they are physically interacting with it. Participants gave their consent to all the above collection and analysis methods prior to the trial. The project was conducted with ethics approval by *Lancaster University*.

5 STUDY RESULTS

Overall our study highlights new insights into how ambient systems support and mediate social interactions, while allowing for social appropriations and different forms of interactions. We observed a variety of responses on our system, and report below on usage patterns and user perception towards their experience with our ambiguous ambient system.

5.1 User Feedback

Our participants provided feedback on their trial experience through Likert statements, open-ended questions, and unstructured interviews. Across these streams of data, we can see several overlapping themes emerge.

5.1.1 General Reception. The Likert data presents a clear picture of overall positive response to the trial experience (Figure 7). Statements that achieved a median of 'Strongly Agree' (SA) or 'Agree' (A) included those expressing that interacting with the system was fun (S7: A); that the participant would interact with it in a casual, social setting (S10: SA); and that not only they enjoyed the system's presence (S1: A), but they believed they enjoyed the time more than they would have had it not been present (S2: A). Across all responses, no participant indicated disagreement to the statements regarding enjoyment (S1), intrigue (S5), and fun (S7) as a result of the system's presence. Furthermore, statements that achieved a median of 'Disagree' were those which described the system as uninteresting (S6), annoying or distracting (S3), and awkward to interact with (S8). None of the statements achieved a median of 'Strongly Disagree'.

Participant's open-ended responses reinforce this positive response further. Looking at Figure 8 we can see that most popular response-themes reflect positive attitudes across questions regarding immediate thoughts to the system (Q1), it's presence while socialising (Q3), and it's impact on mood (Q4). Furthermore, the most common theme (9 responses, 41%) participants cited regarding how AmbiDots affected their mood (Q4), was that it made them feel *happier* or more *upbeat*. The same positive sentiment was found across interviews, several participant claiming *"you know what, I actually found it quite nice"– P8*, *"it was good, really enjoyed it"– P6*, and *"that was brilliant"– P3.*

5.1.2 Relaxation. One of the key themes participants cited as a source for their positive sentiment towards AmbiDots was the idea

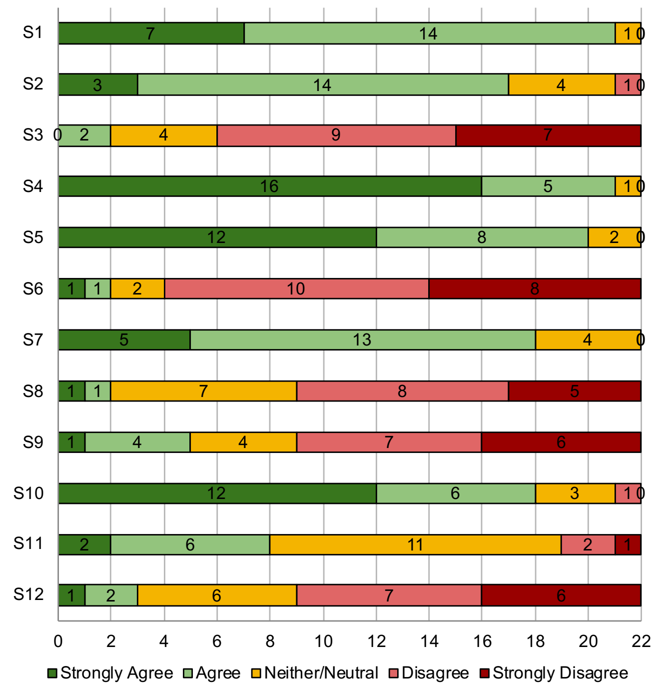

Figure 7: Stacked bar chart visualising the responses to the 12 Likert statements.

of it being *relaxing*. The most popular theme that arose from the open-ended question on immediate thoughts (Q1) were descriptions of the system and experience as relaxing and calming (9 responses, 41%). This same theme was also very popular (7 responses, 32%) in participants responses to the system's impact on their mood (Q4). Across post-trial interviews, one participant described how AmbiDots was *"calming ... stimulating in a sense, but isn't overly doing it"– P10*, with another claiming it *"reinforced [their] ability to relax"– P9*. This participant elaborated, describing how *"[their] ability to relax was already there, because of the comfy chair, the desk, the [drink], the biscuit ... [AmbiDots] build on top of that"– P9.*

5.1.3 Conversational Aid. Many participants also expressed the belief that AmbiDots worked well as conversational aid. We found this to be a very popular theme (11 responses, 50%) to Q3 on feelings towards the system's presence while socialising. As well as being described as a *"good for conversation"– P10* and a good *"icebreaker"– P13*, one participant discussed how they felt AmbiDots served as a good stimuli to rest gaze upon in between eye contact with their peer: *"when you have a conversation, you don't look into someone's eyes constantly, you do look around, and it was nice to look at"– P10.* Along similar lines, another participant who claimed to have worked with individuals with autism expressed their view that AmbiDots may serve well as a stimuli *"for people on the spectrum to focus on"–P3*, facilitating one-to-one social interactions.

5.1.4 Intrigue. A sense of intrigue and interest about AmbiDots was another very popular theme across our data. The two Likert statements which achieved a Strongly Agreed median were regarding intrigue and curiosity towards the system's purpose. This theme

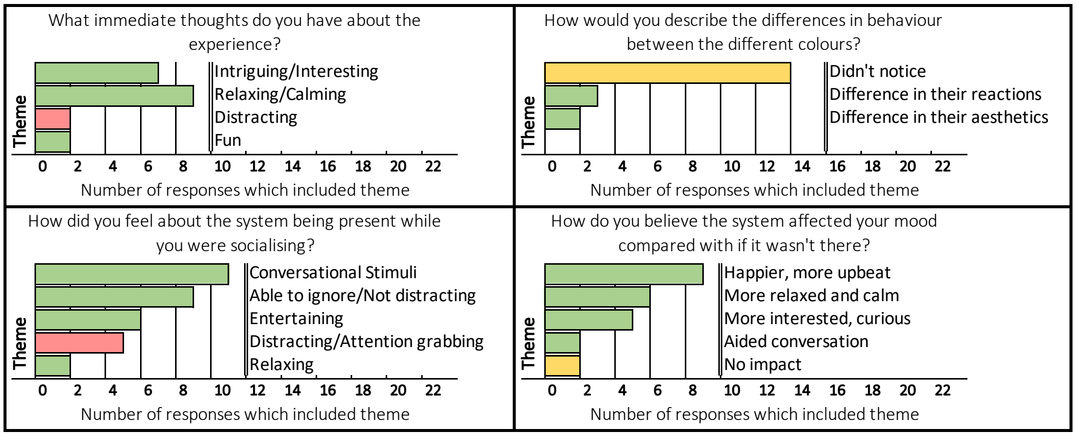

Figure 8: Bar charts visualising common response themes across 4 open-ended-questions

also ranked as 2nd most common among (7 responses, 32%) participant's immediate thoughts (Q1) and was often the first theme in to arise in interviews, with several participants beginning with questions and statements like *"so the question is, what is it?"– P13*, *"what's it intended for?"– P14*, and *"[I] wanted to know what it was all about"– P12.*

5.1.5 Lack of Engagement. In contrast to the theme of intrigue, some participants felt the dots were not very engaging at all. In an interview, one participant described how *"[they] knew [the dots] were doing something, but I think we were very distracted just talking"– P11.* Similarly, another participant claimed *"I was not thinking of [the dots] ... at the same time, I think it has a small influence"– P7.* These claims imply that rather than actively thinking about the system, several participants were instead simply aware of it, but held the conversation with their peer as the primary focus. This idea is backed up by the fact that the large majority of participants (14 response, 64%) did not notice any difference in behaviour between different coloured dots (Q2) — implying that detailed attention was not placed on them.

Along the same lines, one participant explained that AmbiDots was seemly not intriguing enough compared to their conversation to pay attention to: *"it didn't intrigue me enough ... our conversation is more interesting than these dots"– P15.* This sentiment was mirrored by other participants. One explained their lack of interest to be a result of the interactivity being too unclear: *"we tried to discern, oh, are [the Dots] attracted to things ... I think we saw some sort of behaviour in them ... it didn't feel so strongly linked"– P13.* They explained how the lack of clear interactivity lead them to give up attempting to interact, and instead favour conversing for the rest of the trial.

5.2 User Behaviour

In addition to the direct participant feedback, our in-trial recording and observations provide us with more objective insights into how participants responded to the presence of AmbiDots while socialising.

5.2.1 Use Patterns. Looking at the output from our time-stamping application, our visualisation of AmbiDots engagement throughout the trial (Figure 9) provided notable results. Overall, the figure demonstrates great variation in system-engagement patterns and overall duration between each trial — ranging from 0% engagement (T4) to 75% engagement (T7). However, within each trial itself — we see noticeable similarity in engagement patterns between the participant pairs (i.e. at times where one participant is engaged with the system, their pair tends to be engaged as well). This *'mirrored engagement'* effect is demonstrated by the average difference across participant pairs: just 5%, with a maximum range of 13%. This is considerably less than the 75% range across all participants.

Across the 11 trials, Figure 9 reveals that participant-pairs engaged with the system to varying degrees. In the majority of trials (8 out of 11) both participants spent the majority of the time not engaged with the system (choosing to place their attention on their peer or their environment outside of the system the majority of the time instead). Moreover, in 3 of these less-system-engaged trials (T4, T5, T9), engagement duration was a low as less than 10% for both participants; with participants in T4 both showing no engagement at all — choosing to ignore the system completely throughout the entire trial. In contrast to the trials discussed above, in 3 trials (T7, T10, T11), both participants spent the majority of their time engaged with the system. It is worth noting that 2 of these 3 trials (T7 and T11) were our 2 trials where the participants were not familiar with each other before the trial. Lastly, Figure 9 reveals that no participant was engaged with the system more than 75% of the trial duration.

5.2.2 Observations. In addition to this quantitative overview, we also observed several notable behavioural patterns across trials. Generally, participants were not pulled away from their conversation by the system, as evidenced in Figure 9. No participants exhibited any sign of struggle to maintain eye contact with their peer, nor appeared at all distracted when engaged in conversation. Rather, engagement with the system (either observing it or interacting with it) occurred at natural lulls in conversation, in the same fashion as one might look to their drink or meal in our casual, social settings. Moreover, many participants demonstrated

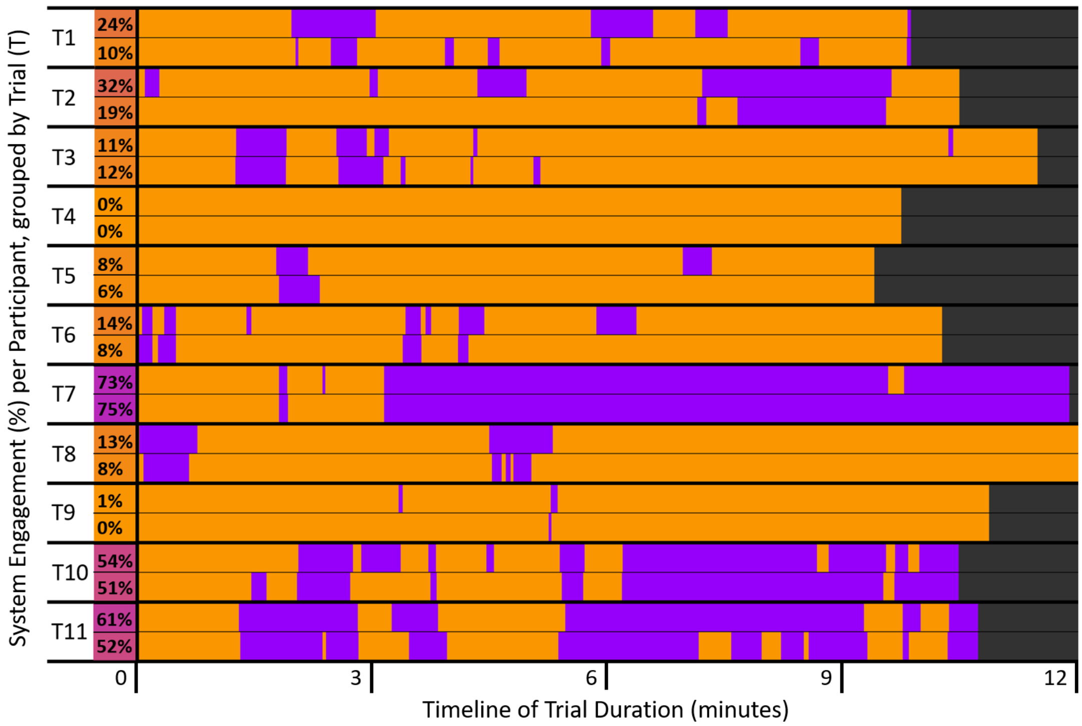

Figure 9: Engagement with System (purple) over trial duration for each participant

with ease the ability to maintain conversation while engaging with the system. This would usually occur at points of more shallow conversation, where less concentration appeared to be required. At points where the dialogue required more thought, participants demonstrated no difficulty in redistributing full attention back to their peer; seamlessly transitioning between the two.

Enthusiasm to interact with the system varied greatly between participants. Some pairs spent large chunks of time seeming to thoroughly enjoy exploring the system's behaviour, theorising and investigating, with their peer, what events it might react to. Some events participants experimented with were common between trials, e.g. waving over the table. However, many participants also demonstrated a variety of unique and imaginative ways of attempting interaction. One pair attempted to flick dots toward each other's side of the interaction space; one participant tried to hide their drinks can from the dots by placing it under a napkin; another tried to use the light reflected from their can to invoke a reaction from the dots; and so on. On the other end of the spectrum, some trials saw pairs happy to seemingly completely ignore the system — only attempt one or two brief interactions if at all — opting instead to engage with their peer and their surroundings. Across all trials, participant behaviour could be placed somewhere on a scale between not interested in the system and intrigued to explore it. We did not encounter any evidence to suggest the system had any adverse impact on any participant's social interaction, or the peer dynamic.

6 DISCUSSION

The current landscape of ambient systems is one predominated by usability concerns. While entire taxonomies have been built to classify Ambient Systems designed to convey information [47], research thus far has neglected to explore the potential of ambient systems to exclusively serve more affective concerns, like our mood and peer interactions — despite the fact that there are many aspects of our lives where these are valued far beyond our task-effectiveness. Indeed, as digital capabilities intersect more and more with our lives outside of productive goals, principles that expand our design vocabulary are more important than ever. In this research, we focus on casual social settings as a prime case study for where ambient systems hold potential to support and mediate our mood and peer interactions. Our results reveal how AmbiDots, underpinned by our 7 design principles, affected mood and peer interaction between participants in one-to-one casual social settings.

6.1 Integration into Social Interaction

Overall, true to the nature of ambient systems, we found participants able to easily ignore AmbiDots, and that the system did not hinder conversations and socialising processes. In contrast, the majority of participants claimed that the presence of AmbiDots actually *improved* their social experience as it made them feel happier, more relaxed and otherwise just enjoy the time more with the system in place. This finding is interesting when paired with the fact that on average, system engagement across trials averaged at just 24%, with 4 participants exhibiting <2% engagement throughout the whole trial (Figure 9). Based on our observations and participant interviews, we theorise that while several participants were observed to enjoy actively engaging and experimenting with the system (T7, T10, T11), for the many who reported an enjoyable experience without having exhibited much engagement (e.g. T4, T9, T5), AmbiDots may have had a non-direct, peripheral influence.

6.2 Ambiguity as a Conversational Aid

The idea of AmbiDots acting as a conversational aid arose in both our observations and user feedback alike. Our observations of the participants casually playing with or glancing at the system while maintaining conversations draws similarities to the way one might fiddle with a straw or other light stimulus while engaged in casual conversation. The fact that several participants independently cited AmbiDots as aiding their ability to both relax, and specifically as conversational aid, suggests that AmbiDots presented *genuine utility* to users in this respect. We theorise an important element of our ambient system that enabled this balance between light stimulus and not grabbing attention, was the fact that AmbiDots *does not attempt to communicate any information to the user*, which could potentially distract from the subject of attention (e.g. the conversation topic). In addition, we believe the placement of the interaction space — easily accessible within the user peripheral view when facing their peer, to also have been an important factor.

6.3 Curiosity as Catalyst for Interaction

Across our study trials, we observed a cyclic interplay between periods of active interest and engagement with the system, and periods of it being left to rest in the periphery. When immersed in conversation, participants would devote their entire attention and eye contact on their peer, unaffected by the system's behaviour. As they approach natural conversational lulls however, participants often allowed their gaze to drift down to the AmbiDots visualisation. After a short period, this appeared to (re-)ignite their curiosity, leading them often to interact for a short period before conversation began again - continuing the cycle. This pattern is evidenced by the bursts of system engagement throughout Figure 9.

The curiosity and intrigue as to AmbiDots's purpose reported by many following their time with the system is understandable, given that ambiguity [22] and curiosity-driven design [57] were two central resources underpinning our design principles. Our intention was for this intrigue to motivate playful interaction, and we proved successful in several trials (T7, T10, T11). However, it may have unintentionally been the case for many that a lack of clarity as to how the dots were reacting to events, and perhaps a resulting confusion, may have demotivated continued exploration. In reflection, we believe that in employing ambiguity to invoke curiosity, care must be taken to avoid interactions becoming confusing, or seemingly inconsistent, lest playful investigation be abandoned.

7 CONTRIBUTION, LIMITATIONS, AND FUTURE WORK

Our work contributes design principles, a system design, and empirical data demonstrating how an ambiguous ambient interface can mediate social interactions. This provides steps towards a broader understanding of how systems might be designed in casual social spaces to better meet our contextual values. We believe technology such as AmbiDots may become an integral aspect of interior design in casual social spaces — serving alongside existing elements of experiential enhancement, including furniture, room layout, lights, wallpaper, and so on. Our study was conducted in a pseudo-social environment. While we expect similar results to emerge when deployed in-the-wild, we propose that future work could examine how AmbiDots — or similar technology — affects social interactions in field studies. Finally, we propose that our design principles are a step towards operationalising the ideas and concepts of calm computing [62] with peripheral interaction [4], and affective UI [18] into concrete actionable design recommendations.

8 CONCLUSION

This paper explores how ambient systems support and mediate casual social interactions. Our findings contribute a first-exploration of a non-task-orientated ambient systems research space by documenting the design of AmbiDots (an affect-oriented system) and its analysis and subsequent discussion through a 22-participant user study. In pursuit of design criteria more appropriate in meeting our contextual values than usability — we began by establishing affect-centric system design principles. We present the AmbiDots system as a means of examining and evaluating our principles in practice. The user study provides a series of both user-reported and researcher-observed insights into how systems designed from these principles affect users in terms of mood, behaviour, and peer interaction. Our insights contribute implications for future affective ambient system design, as well as point to potential use cases and benefits on user experience in casual social settings.

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