Towards Usable and Acceptable Above-Device Interactions

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Abstract
Gestures above a mobile phone would let users interact with their devices quickly and easily from a distance. While both researchers and smartphone manufacturers develop new gesture sensing technologies, little is known about how best to design these gestures and interaction techniques. Our research looks at creating usable and socially acceptable above-device interaction techniques. We present an initial gesture collection, a preliminary evaluation of these gestures and some design recommendations. Our findings identify interesting areas for future research and will help designers create better gesture interfaces.

Author Keywords
Acceptability; Above-Device; Gestures; Mobile Phones

ACM Classification Keywords
H.5.2 [User Interfaces]: Interaction Styles.

Introduction
Touchscreen interaction has become the main way of interacting with mobile phones. This is often a highly engaged interaction, requiring both visual attention and precise touch input as users search the display and select what are often small targets. Users may not always be willing or able to give this much attention to their phone, for example when in a meeting and not wanting to appear rude or when

Gesture Sensing

Proximity Sensors: These sensors detect nearby objects with a range of around 5 to 30 cm. Multiple sensors can be used to detect hand [5] and finger [2] movements.

Magnetic Sensors: Magnetic field sensors, already in phones, can detect movement of magnetic objects like rings [3, 4]. Gestures, such as precise finger movements [3] for pointer control, can be sensed through materials and anywhere around the device.

Cameras: Most phones have cameras which can be used for detecting gesture interaction, for example tracking fingers [6]. Placing a lens over the camera lets phones detect simple gestures, like waving, from a distance [10].

Depth Cameras: Google's *Project Tango* [1] has a depth camera and dedicated vision processing resources. Depth cameras can detect hand orientation and pose as well as movement.

focusing on another task and not wanting to be disturbed. Touch may also be unavailable for input, for example when washing dishes or exercising and hands are wet. In these situations, gesturing with a hand in mid-air near a device would let users interact with their phones when direct touch is unavailable or inappropriate.

Gestures above a device on a table could be particularly useful as people typically keep their phones on a table or desk throughout the day when at home and at work, largely for easy access [9]. Users particularly want easy access to their notifications [9]. Above-device gestures let users dismiss unwanted interruptions while busy [7] and would let users perform less involved interactions, such as frequently checking for notifications, without having to lift their phone.

Our research looks at designing usable and acceptable above-device interactions. We gathered above-device gesture ideas from brainstorming sessions and then chose some of these gestures for further evaluation. A preliminary evaluation looked at the usability and social acceptability of these gestures. We present our findings from these studies and recommendations for creating better above-device interfaces.

Related Work

A variety of sensing technologies (discussed in the sidebar) have been used for detecting mid-air gestures near mobile phones. In this section we look at some gesture interfaces with a particular focus on the interactions they support.

Some gesture interfaces detect finger movements for cursor control, letting users interact with small devices using a larger space. *SideSight* [2] used ten proximity sensors on each side of a mobile phone to detect gestures. Users could interact on either side of the device, using the surrounding table surface for input. *Abracadabra* [3] used magnetic sensing to track finger position for controlling a cursor on a smart-watch. Users could also gesture by making circular or semi-circular paths. Finger position has also been used for mid-air typing [6], this time using a camera to sense finger movements over a virtual keyboard.

Other interfaces detect less precise hand movements and gestures. *HoverFlow* [5] used upwards facing proximity sensors to detect above-device input. Users gestured over the display, for example swiping left or right, lowering a hand, and rotating a hand. Gestures were used to navigate a colour palette. *Surround-See* [10] let users gesture from across the room, for example waving at their phone to silence it. Ketabdar *et al.* [4] used magnetic sensing to detect a small vocabulary of gestures, for example detecting gestures by a hand wearing a magnetic ring.

Some mobile phones can already detect above-device gestures. The Samsung Galaxy S4 phone can detect hand movement over the display, letting users swipe through image galleries and scroll through documents. Some Nokia Lumia phones detect hands hovering over the proximity sensor, letting users glance at their notifications without unlocking the display.

Above-Device Gestures

Despite advances in gesture sensing approaches for mobile phones, little is known about how best to design usable and acceptable above-device interactions. Our work begins to address this. We focus on above-device gestures because phones are often kept on desks and tables [9]. Gestures over phones would let users interact casually [7]. Users could also gesture when touch is inconvenient or inappropriate, for example to navigate a recipe without getting their phone messy or having to repeatedly wash their hands.

We started to explore the above-device gesture design space by brainstorming gesture ideas with participants. By taking

Brainstorming Sessions

Procedure: We first discussed scenarios where above-device gesture use may be appropriate. Then we asked participants to think of a gesture for common phone actions (listed in Table 2) while thinking aloud. There were no constraints on gesture designs and gestures could be re-used. We placed a phone in front of participants for use as a prop. After participants chose their gestures we filmed them demonstrating them. We also recorded audio for the entire session. These recordings were later analysed.

Participants: Fifteen people took part in these sessions (three female, mostly university students). Participants were recruited through email lists and were paid £6.

Gestures: We collected 175 gestures, of which 49 were unique. Three were two-hand gestures and one was performed on the table surface.

a participatory approach to gesture design we hoped to discover gestures which users would be willing to use. These sessions would also give insight into how we can design better above-device interfaces. We chose gestures from these design sessions which we evaluated further using an online survey. Our survey evaluated gestures in terms of design and social acceptability [8].

We now present the outcomes of these brainstorming sessions and our gesture evaluation. From these outcomes we create design recommendations which will help others design better gesture interfaces. Our work also contributes some usable and socially acceptable gestures for common mobile phone tasks. Finally, our findings identify interesting directions for future mobile phone gesture research.

Brainstorming Sessions

We gathered initial gesture ideas through a series of brainstorming sessions with mobile phone users. We also discussed how interfaces should react to gestures. Our procedure for these sessions is described in the sidebar. We chose two gestures for each action, inspired by the gestures proposed by our participants. Our gesture choices generally represented the most popular gestures created by participants. Figures 1 to 8 show some of these gestures.

As well as identifying suitable above-device gestures, we also analysed audio recordings and videos of participants demonstrating their own gestures. This gave insight into why people chose certain gestures and helps us understand how to create better above-device interfaces. We now discuss some key themes found from this analysis. Themes are coded (e.g. *GF* for *Gesture feedback*) for later reference.

Gesture feedback (GF)
Participants were uncertain about how well their gestures would be detected, especially those who were unfamiliar with other types of gesture interface (e.g. Kinect). Effective feedback is needed to help users overcome uncertainty and gesture confidently. Some participants said visual feedback would be ineffective because their hands gestured over the phone display. Above-device interfaces may have to give other types of feedback. Tactile feedback would not be felt (unless holding the phone) and some thought constant audio feedback may be unacceptable around other people.

Metaphorical gestures (MG)
Many gestures were based on metaphors or familiar interaction techniques. For example, some gestures imitated pointing with a cursor and others were based on a telephone metaphor with users lifting their hand to mimic lifting a phone from the receiver. Metaphors may have been chosen because the metaphor would be understood by others observing the gesture performance. If the meaning of a gesture is easily understood by other people, users may feel more comfortable using it [8]. Gestures based on metaphor may also be easier to remember.

Gesture mechanics (GM)
We observed a variety of different gesture mechanics. Some people performed swipe gestures with their entire hand, while others preferred more subtle motions with one or two fingers. Gesture "size" also varied; some participants used small, subtle hand movements over the phone only while others would perform larger versions of the same movements. Most participants gestured around 10 to 20 cm above the phone prop.

Social acceptability (SA)
One of our participants said she would be uncomfortable performing some of her gestures in public in case people saw her and thought she was gesturing at them. Cultural interpretations of gestures could also be an issue.

Survey Design

Procedure: Gestures were shown in a random order. We showed a video of each gesture along with a text description. We encouraged participants to try gestures above their own phone. Participants then rated the gesture (see below) and could give freeform comments.

Gesture Ratings: We asked participants to rate gestures in terms of: how appropriate is it for its action, how easy is it to perform, how memorable might it be, how likely would they be to use it. Ratings were on a seven-point scale.

Acceptability: We used a similar design to [8], modified after correspondence with the authors. We asked participants if they thought each gesture was appropriate to use in a variety of social situations (Table 1). Responses were yes/no checkboxes.

Participants: Forty-one people (aged 18-65, nineteen female) completed the survey.

Gesture Evaluation Survey

We evaluated our chosen gestures using an online video survey. We chose to use an online survey because it would let us reach a wider international audience and was found by Rico *et al.* [8] to be a useful method. Our survey aimed to evaluate usability aspects of our gestures as well as looking at how socially acceptable they are. Our findings could then be used to identify usable and acceptable gestures for above-device interfaces. This was also a first look at the social acceptability of above-device interaction, to see if people would be willing to interact with their phones in this way. The sidebar on the left describes our survey design.

For each gesture, we calculated an overall score as the sum of its four ratings (appropriateness, ease of use, memorability and likeliness of use). This gave a score from four to twenty-eight, where higher scores are better. We also calculated an acceptability score for each gesture as the percentage of positive responses (as in [8]). A score of 100% indicates that participants found the gesture acceptable in all situations. Table 1 shows mean acceptability scores for each social situation; these are similar to findings for device-based gestures [8].

We compared both gestures for each action to see if one was rated significantly higher, in terms of overall score and acceptability score. We used the Wilcoxon signed-rank test to compare all ratings. Acceptability scores were highly left-skewed so were compared using Wilcoxon's test rather than a t-test. Table 2 shows gesture and acceptability scores, along with results from the Wilcoxon test.

Situation	*Accept.*	*Situation*	*Accept.*
Home, alone	89%	Home, family	78%
Work, alone	86%	Work, colleagues	72%
Public, strangers	60%	Public, friends	66%

Table 1: Acceptability in social situations.

Design Recommendations

Qualitative analysis of audio and video recordings from our design sessions helped identify common themes in expectations of an above-device gesture interface. Our gesture survey provided a chance to probe some of these issues further. These recommendations arose from the outcomes of both studies and should help designers create better above-device interfaces. We refer back to themes from our brainstorming sessions when appropriate.

Give non-visual feedback during interaction

Feedback during gestures is important because it shows users that the interface is responding to their gestures and it helps them gesture effectively *(GF)*. However, above-device gestures take place over a phone so visual feedback will not always be visible. Instead, other modalities (like audio) should be used.

Make non-visual feedback distinct from notifications

Some participants suggested that they may be confused if feedback during gesture interaction was like feedback used for other mobile phone notifications *(GF)*. Gesture feedback should be distinct from other notification types. Continuous feedback which responds to input would let users know that feedback is being given for their actions.

Emphasise that gestures are directed towards a device

Some participants in our studies were concerned about people thinking they were gesturing at them rather than at a device *(SA)*. Above-device interactions should emphasise gesture target by using the device as a referent for gestures and letting users gesture in close proximity.

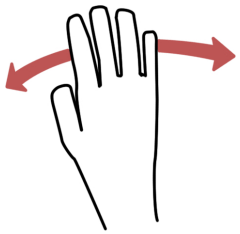

Figure 1: Swipe.

Figure 2: Point and Tap.

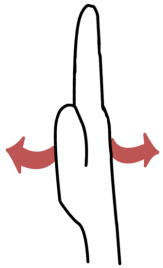

Figure 3: Flick.

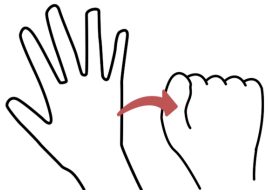

Figure 4: Scrunch.

Gesture	Median Score	Mean Acceptability
Check messages		
Swipe	21	78%
Draw Rectangle	13	70%
	Z=-4.45, p<0.001	Z=-1.55, p=0.12
Select item		
Finger Count	20	73%
Point and Tap	26	93%
	Z=-4.41, p<0.001	Z=-2.70, p=0.005
Move left / right		
Swipe	24	87%
Flick	24	84%
	Z=-0.15, p=0.88	Z=-0.60, p=0.55
Delete item		
Scrunch	23	85%
Draw X	21	79%
	Z=-0.98, p=0.33	Z=-0.86, p=0.39
Place call		
Phone Symbol	17	64%
Dial	20	74%
	Z=-2.00, p=0.04	Z=-1.84, p=0.07
Dismiss / close item		
Brush Away	20	82%
Wave Hand	20	72%
	Z=-0.51, p=0.61	Z=-1.62, p=0.11

Gesture	Median Score	Mean Acceptability
Answer call		
Swipe	19	80%
Pick Up	18	66%
	Z=-0.48, p=0.64	Z=-2.65, p=0.008
Ignore call		
Brush Away	20	79%
Wave Hand	20	77%
	Z=-0.02, p=0.99	Z=-0.36, p=0.72
Place on hold		
One Moment	20	72%
Lower Hand	19	68%
	Z=-2.04, p=0.04	Z=-0.57, p=0.57
End call		
Wave Hand	21	71%
Place Down	23	76%
	Z=-1.51, p=0.13	
Check calendar		
Thumb Out	10	59%
Draw ? Symbol	17	72%
	Z=-4.04, p<0.001	Z=-1.88, p=0.06
Accept and reject		
Thumb Up/Down	15	64%
Draw Tick/Cross	20	78%
	Z=-3.76, p<0.001	Z=-3.01, p=0.003

Table 2: Scores and results of Wilcoxon's signed-rank tests. Significantly higher scores ($p<0.05$) are highlighted.

Support flexible gesture mechanics

During our brainstorming sessions, some participants gestured with whole hand movements whereas others performed the same gestures with one or two fingers *(GM)*. Gestures also varied in size; for example, some participants swiped over a large area and others swiped with subtle movements over the display only *(GM)*. Above-device interfaces should be flexible, letting users gesture in their preferred way using either hand. Social situation may influence gesture mechanics *(SA)*. For example, users in public places may use more subtle versions of gestures than they would at home.

Figure 5: Dial.

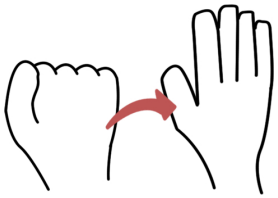

Figure 6: Brush Away.

Figure 7: One Moment.

Figure 8: Draw ? Symbol.

Enable complex gestures with a simple gating gesture
Our participants proposed a variety of gestures, from basic movements with simple sensing requirements, to complex hand poses requiring more sophisticated sensors. Always-on sensing with complex sensors will affect battery. Sensors with low power consumption (e.g. the proximity sensor) could be used to detect a simple gesture which then enables more sophisticated sensors. Holding a hand over the phone or clicking fingers, for example, could start a depth camera which could track the hand in greater detail.

Use simple gestures for casual interactions
Casual interactions (such as checking for notifications) are low-effort and imprecise [7] so should be easy to perform and sense. Easily sensed gestures lower power requirements for input sensing and allow for variance in performance when gesturing imprecisely. Users may also use these gestures more often when around others so allowing variance lets users gesture discreetly, in an acceptable way *(SA)*.

Future Work

We identified the importance of giving effective feedback for gestures. Visual feedback will often be inappropriate because users will be gesturing over the display. Instead, other modalities such as audio and tactile should be used. Our research will look at how feedback can be given in the space above the device. Gesture interfaces also need to be flexible, letting users vary how they gesture and using different gesture sensing modes in different situations. We will explore these issues more in future work.

Conclusion

Our research looks at how to create usable and acceptable above-device interfaces. In this paper we presented two studies: a design study where we gathered gesture ideas and an online evaluation where we looked at some gesture ideas in greater detail. We contribute a collection of gestures for some common mobile phone tasks and an initial evaluation of these gestures. Qualitative analysis during these studies gave insight into above-device design issues. We contribute design recommendations based on these findings.

Acknowledgements

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