Chapter 2
"Unseen, Yet Crescive": The Unrecognized History of Peripheral Interaction

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Abstract Peripheral interaction, the reflexive and reactive pre-attentive use of tools and techniques on the periphery of conscious attention, has always been a fundamental part of how humans interact with the world. In fact, it is very likely that our ancestors have been interacting peripherally since well before they were human. In the midst of searching for new paradigms for interaction with the ubiquitous networks of embedded systems that fill our homes and workplaces, it might be a good idea to look at the peripheral tasks we are already performing. Ironically, being on the periphery of our conscious attention, this complex assortment of internal and external interactions has gone largely unnoticed. In this chapter, we use the principles of anthropology-based computing to follow Mark Weiser's advice and drag these tasks to the center of our attentive focus for a closer examination before deciding whether or not to relegate them once more to the borders of our perception.

Keywords Peripheral interaction · Calm technology · Anthropology-based computing (ABC) · Triune brain · Brown's Representation of Anthropogenic Interaction in Natural Settings (BRAINS)

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2.1 Introduction: An Anthropologist on Earth—*Observing Peripheral Interaction Among Humans, In re: Their Natural and Constructed Environments, Their Communities, and Their Cocktail Parties*

Can humans interact with information on the periphery of their senses? Yes, yes, of course peripheral interaction (PI) exists. Can you hear the sound of a car dopplering past you as you ride your bicycle? Does the changing noise inspire in you a change in either deliberate or unconscious behavior—or both? Any normal, healthy human is in a constant state of PI throughout their waking hours. In fact, I will argue that most of our interactions are so thoroughly peripheral that we execute them without even noticing. That is the reason for the title of this chapter.

> And so the Prince obscured his contemplation
> Under the veil of wildness, which, no doubt,
> Grew like the summer grass, fastest by night,
> Unseen yet crescive in his faculty."
>
> William Shakespeare,
> Henry V, Act 1, scene i

Most of our interaction with the world around us is so unconscious and so fundamental that it is not only "obscured… under the veil" of our more obvious interactions, but it continues to happen while we are sleeping. Respiration and digestion take place on the periphery of our attention, until and unless some problem arises in their reflexive cycles. The problem pushes them to the center of our attention.

Let us move upwards through the layers of simple and complex reflexes processed in the peripheral nervous system, those controlled in the central nervous system, and even those managed in the cerebellum.[1] Consider typing or mousing, holding a book, or holding a stylus: any task in which you unconsciously coordinate multiple channels of neurological input in order to unconsciously coordinate complex neuromuscular interaction to serve your unthinking intent.

We learn these tasks reflectively and practice them until they move to the periphery of our attention. There, on the periphery, they grow and develop outside of our conscious awareness, becoming what Shakespeare described as "…unseen yet crescive.[2]" In fact, all computing tasks and every other task that we perform—not for the first time, but with the unconscious rituals of inattention that come with familiarity—are taking place on the periphery and stay there until an unexpected perception surprises us enough to be noticed.

In this chapter, I will reintroduce a simple model of the iterative feedback loops with which we perform these tasks at the most basic neurological level

[1]Cerebellum = the part of the brain in which complex reflex patterns are coordinated.

[2]Crescive = developing over time without conscious direction.

(Freides 2001) and tie them to the theory of anthropology-based computing (ABC) (Brown 2013b) through the concepts of dynamic environmental focus (DEF) and general human interaction (GHI) (Brown 2016). All of these support a three-tiered model of human interaction based on MacLean's triune brain (MacLean 1973). I call this new triune model Brown's Representation of Anthropogenic Interaction in Natural Settings (BRAINS) and propose that it provides a plausible explanation of the simple mechanics that enable and even force us to use PI. This model also allows for a possible explanation of two well-established psychological concepts: the cocktail party effect (CPE) (Cherry 1953; Moray 1959; Golumbic et al. 2013) and Csikszentmihalyi's "Flow" (Csikszentmihaiyi 1990). Before we get any further into this chapter, please allow me to offer a quick illustration of both CPE and "Flow."

Cherry described the natural human ability to focus on a single one of many audio streams in a noisy and crowded situation like a cocktail party (Cherry 1953). Moray took this further and showed that CPE is strengthened by emotional ties to the speaker or the words spoken (Moray 1959). Golumbic took that still further and showed that the brain recognizes all of the streams of conversation as noise, but recognizes only the attended voice and the affective factors as language (Golumbic et al. 2013). Let us take a quick look at this from an anthropological perspective. The cocktail party may actually be going on around you at a physical gathering, it may manifest as multiple streams of digital interaction—separate and shared overlapping strings of SMS and email, for example—or it may be a combination of the two, as when you exchange multimodal messages with many friends while in a crowded and noisy space. The human experience of filtering multiple streams of sensory information in real time predates both digital technology and cocktail parties.

With the exception of rare cases of brain injury or disease (Mirsky 1987), humans naturally process multiple streams of information, most of which are not at all central to their conscious and deliberate ratiocination[3] at any given time. There are situational exceptions, such as in cases of "Flow," that state in which we feel as though we are performing at peak ability—regardless of the specific setting—immersed in our performance and feeling as though our perception of the outside world has disappeared (MacLean 1973). In "Flow," we believe that nothing exists but the moment and the task, and we are certain that we are thinking and reacting faster than usual. We will return to this idea a little later in the chapter and offer an explanation for how and why we feel that way. For now, I hope that it is clear that the case of "Flow" as a recognized topic of study, and a commonly understood event, is a fine negative illustration of the common nature of PI. If PI were not the common state, then the disappearance of peripheral streams of input would not be at all remarkable, and it would never have proven necessary to coin the term "Flow."

[3]Ratiocination = rational thought, reflection.

2.2 Peripheral Interaction: As We DO Think—*Explaining the Mechanisms that Underlie "Peripheral Interaction," "Flow," "MultiTasking," "the Cocktail Party Effect," and "Cross-Generational Habit"*

In his 1945 monograph "As We May Think," Vannevar Bush predicted that technological innovations in the workplace would change the way that we use our brains and the way we value their use (Bush 1945). His predictions may, in time, prove not only to be visionary (Novak 2010), but even to be correct. Certainly, his thought experiment produced the mental model that underlies the GUI desktop on every one of our electronic devices (Smith et al. 1985). Unfortunately, the vast majority of papers referencing his seminal paper seem to ignore the most important part of his message, focusing on the technological aspect of his proposal, rather than the human (Reingold 1987).

Bardzell and Bardzell have proposed that this imbalanced perspective in computer science is precisely why Weiser's prediction of ubiquitous computing has come true, while his call for Calm Technology has largely been abandoned (Bardzell and Bardzell 2014). I propose that the answer lies in the fact there is a fundamental flaw in the way that most of us see ourselves in the world. We imagine that we are cognitive creatures—rational brains reasoning their way through life, while floating inside pools of life-giving nutrients that balance precariously on the top of our spines. We are the great thinking ape, Homo sapiens, deliberately shaping the world around us and consciously interacting with our environment and our fellows.

This is nonsense.

Well, the idea that we live inside a precariously balanced pool of nutrients is fairly accurate and can be taken further into the abstract and away from our egocentric perspective, as illustrated so brilliantly in Dawkins' argument that the true function of humans is to serve as a nearly countless series of life pods for the primordial selfish genes that we carry around (Dawkins 1976). Be that as it may, our image of ourselves as rational creatures is a delusion. Rational thought is used sparingly by most humans and is quite literally counterintuitive. As scientists, we are supposed to apply the "scientific method," a series of deliberate techniques designed to force us to be rational and to make it easy for our peers to check and see whether we have succeeded—not in finding specific results, but in running our experiments rationally.

Outside of the laboratory, most of our interactions do not involve decisions at all, but are carried out reflexively. That is how we balance in our chairs and on our feet, and it is how we carry out all of the complex interactions that let us use our bodies to do what we want to do. Furthermore, most of the decisions we do make are not made rationally as evinced by the simple fact that we do not take the time to deliberate. Most of our decisions are made quickly and "intuitively," and we often do not consciously realize that we have made a decision until we find ourselves carrying out the resultant action—or failing to.

Consider what happens when you decide not to take another potato chip. Have you ever found yourself eating one anyway? Did you have to push the bowl away to force yourself to stop? Doesn't that very idea imply that there were at least two processors working in your head—and that one was being rational while another was not? This is where our myth of human multitasking takes root. Can you do more than one thing at once? Clearly. Are you willing to accept that you have conscious control of only one of them at a time? Why, that would mean that talking while driving is dangerous! Preposterous! We delude ourselves into believing that we are in control of what we are doing and of what we have done.

I believe that it is an observable fact that most of our non-reflexive interactions are not deliberate, but are based on pre-attentive decisions and patterns of behavior. Some of these learned and practiced patterns have been an unconsciously accepted part of our social and environmental lifestyle for much longer than we realize. I have spoken elsewhere about cross-generational habit and how it shapes our behavior (Brown 2013b, 2016). This is why, for example, lights have been glaring blindingly at us for as long as we have had internal lighting—even though we have long had the technology to make lighting soft and diffuse. The same unthinking pattern applies to the design of chairs and steering wheels and computer mouses. I believe that this is due to the fact that once we have learned to use these tools at the periphery of our attention, we do not deliberately examine them again—we do not even consider that they are changeable.

I believe that our ability to focus our thoughts is not the great gift that we like to consider it to be. Consider how often mis-focused attention leads to accidents, injuries, and death. That phones divert our attention, while we are driving is now considered the leading cause of death for young adults around the world (World Health Organization 2014). But I believe that it is not simply a question of being distracted by a sudden noise. Though the function of a message alert is to attract the conscious attention of the recipient, I believe that—because of prolonged experiences of Flow while texting—the message alert attracts the attention of the two "deeper" processing systems in our minds. As a result, the young driver reacts without thinking—with systems much faster than conscious thought—averting her eyes and her focus from the road to the phone.

To explain that reaction and other types of cognitive dissonance, I will propose a theoretical model of the human mind (Brown 2015a). We will look at how it offers explanations for PI (Bakker 2013) and Weiser's "Calm" (Weiser and Brown 1996), as well as a number of other popular concepts. Unlike many other models of the mind and the brain, this model is not intended to reflect the biochemical or electrical properties of the cellular structure (Freides 2001; Cooper et al. 2003), nor is it intended to associate specific realms of thought or behaviors with specific regions of the neocortex (Freides 2001; Broca 1861).

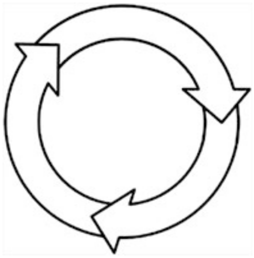

Fig. 2.1 An iterative feedback loop

This model of the mind is purely conceptual, and it is intended to assist non-specialists in the visualization of the processes that are actually going on when humans receive, ratiocinate, and respond to stimuli from the outside world. The key to this model, though, is that it is not focused purely on rational thought, but that it illustrates the simultaneous (and much faster) processing that goes on in other more primitive parts of the neural and cerebral structure. Including these other structures allows for a simple understanding of the difference between "multitasking" and "task-switching"; of the difference between "reflex" and "reaction"; and of the difference between the emotionally overripe and intellectually fragile manner in which humans usually respond to stimuli and the actual process of rational thought. Before we tour the structure of this new idea, let us review a few of the foundations on which it has been built.

2.3 Iterative Feedback: As We May Learn—*Explaining the Mechanisms that Underlie Our Interactions with the World Around Us and How We Learn from that Interaction*

Human understanding of the world around us is built up from iterations of simple feedback loops, as shown in Fig. 2.1, which has been discussed in greater detail elsewhere (Brown 2013b). Taking the model of how feedback loops iterate at a neurological level, we perceive the world, process what we perceive, and act based on the results of that process. Then, we perceive the world again and see what has changed. Let us look at a simple exchange. We are constantly receiving proprioceptive data about the position and orientation of the different parts of our bodies and processing them unconsciously in order to maintain our balance or move precisely. Corollary discharge,[4] for example, signals the intent to initiate a movement. We perceive and react to these signals in unending, overlapping iterative

[4]Corollary discharge = this is a copy of the internal signal generated by our neuromotor system when we execute a movement. The copy seems to serve to let us know whether our body is moving under our own control, or under the influence of some other factor.

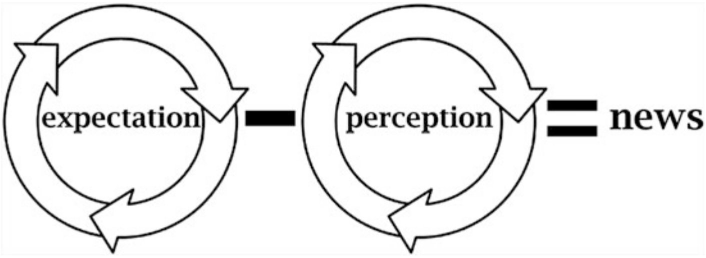

Fig. 2.2 As we may learn

feedback loops. A comparison that detects proprioceptive information regarding repositioning, but does not detect corollary discharge, informs us that we have been passively moved. Disorders in corollary discharge can cause us to attribute our actions, or even our thoughts, to others (Freides 2001; Frith and Done 1989).

Figure 2.2 shows how we might learn through these iterative cycles. This theory posits that it is the difference between what we expect and what we perceive that allows us to recognize new information and adjust our mental model (Staggers and Norcio 1993). The application of the same iterative cycle that allows us to maintain our posture, as a model for how we might learn to interact with the world, has recently received some evidentiary support in a publication from the Mayo Clinic (Stahl and Feigenson 2015).

One's understanding of the world grows and develops through the matching of experiences against expectations in the same kind of iterative feedback loop. The expectation that one holds about how to interpret environmental stimuli adapts to new information about the possibilities of stimuli, and more correct or mature (that is, more accurate or more useful) models are formed (Staggers and Norcio 1993).

This is more than a series of reactions, in that the comparison between the expected and the perceived allows us to modify our expectations, to build new models of the world around us and of our place in it. These models could include the models of self that allow us to navigate the physical spaces around us without bumping into other people and societal models that allow us to navigate the social spaces around us with the very same goal. It has even been shown that the use of well-understood mental models can facilitate interaction, with the possibility of making new devices seem intuitive (Brown 2015b).

Some of these iteratively developed models are private and reflexive, but others are shared and reflective.

2.4 Playing with Models: As We May Think We May Think—*Using Our BRAINS to Explain the Mechanisms that Underlie Simple Reflexes, Coordinated Reflexes, Pattern Recognition, Intuition, and Ratiocination*

In the brief history of HCI, several models of interaction have become popular. I have dealt with these in detail elsewhere (Brown 2014), but will refer to them here in passing so that the astute reader knows where to look for the original work. Norman proposed a cycle of interaction in which people incorporate their tools into their natural iterative behaviors (Norman 1988). Abowd and Beale created a *tennis court-style model* in which "user" and "system" communicate across an "interface" (Abowd and Beale 1991). MacKenzie added details to their model, in order to more closely reflect the processes taking place in virtual environments (MacKenzie et al. 1995). Coomans and Achten added multiple streams of input and output in their proposal of a "Design Information System" for VR (Coomans and Achten 1998). In all of these, two problems persisted: first, the fact that the *tennis court-style model* forced us to focus on the net, rather than the players (Brown 2016) and second, the deliberate ignorance of the possible importance of the fact that humans interact to different stimuli at different speeds (Hyman 1953).

Throughout history, those who have examined the workings of the human mind have proposed multitiered models based on reaction times and styles. Aristotle shared Plato's model of a three-tiered concept of the human mind—one based on the natural functions of the body, one centered on desires, and a final, deliberate one that was the realm of clear thought (Hammond 1902). Freud believed in a trifurcate mind ("ego," "superego," and "id") (Freud 1961), as did Jung ("collective unconscious," "self," and "personal") (Chang 2014).

MacLean proposed a triune model based on the evolution of the physical brain (MacLean 1973) that was popularized in Carl Sagan's book the Dragons of Eden (Sagan 1977). More recently, Kahneman's two-stage model of the brain has also attempted to explain the fact that some of our thinking is fast and emotional, while some is slower, more deliberate, and logical (Kahneman 2011).

The earlier model of interaction associated with anthropology-based computing was referred to as simply as the ABC model of HCI. BRAINS are a model of GHI, not limited to the use of machines or tools. This model explains that, according to the way that the brain has developed in different animals and in accordance with the way that the human brain can be seen to develop in utero, we have at least three separate processing systems, each of which is capable of separately perceiving, processing, and responding to external stimuli.

In Fig. 2.3, we represent those different evolutionary levels in two different ways, both of which come from the notebooks of the author and are used here as they have been used elsewhere (Brown 2013b). Figure 2.3a shows three iterative cycles. The largest represents our reflexive system, and as such, it overlaps between

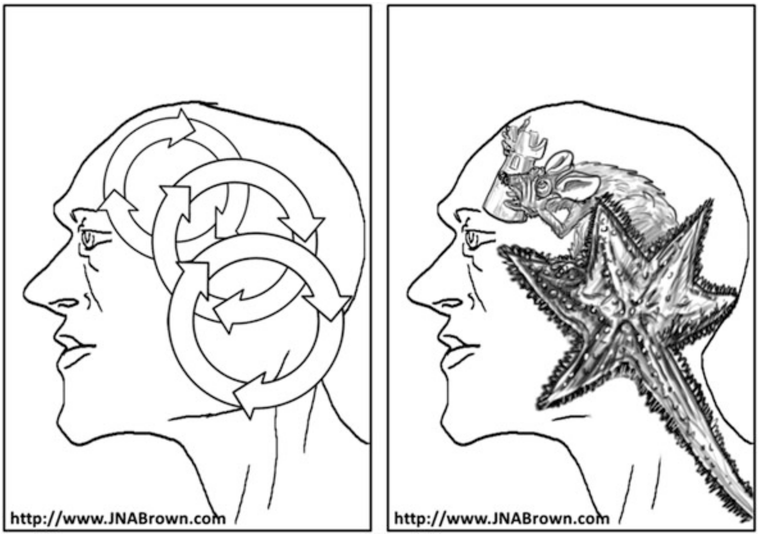

Fig. 2.3 Two renditions of the BRAINS model of general human interaction

the brain and the body. This is our primary level of interaction with our environs—from breathing the air to standing upright. The next cycle down (in z-depth and in control) is the reactive system, where we react quickly and emotionally to the world around us. Below that, and much smaller, is the reflective system in which we think logically and intellectually.

Figure 2.3b shows the same hierarchy, but uses cartoons to represent the different types of processing and the relationship between them. The foundation of the illustration is the echinoderm (starfish or seastar), chosen for this role because it has peripheral reflexes and seems to coordinate those reflexes through an unknown system that could be a precursor to the central nervous system. The echinoderm passes some sensory information on to wildly emotional protoprosimian.[5] This creature is really much too late in the evolution of life to represent fast, visceral pattern recognition, but has been chosen because it is a more pleasant and sympathetic ancestor than a bird or lizard. The protoprosimian is busy almost all of the time and is almost always emotionally charged. Occasionally, she either whispers or shouts into the ivory tower she carries in her hands. Inside this ivory tower, isolated and only capable of indirect interaction with the real world, is our reflective system.

Preliminary versions of this model have been presented before (Brown 2014, 2015b). Here, in the context of PI, we will present the model again in order to illustrate the anthropological basis of the human ability to interact with information

[5]Protoprosimian = ancient relatives who predate the division between our dry-nosed ancestors and their wet-nosed cousins.

at the center of our attention, while also keeping track of information that ranges from mildly to extremely peripheral. Let us take a look at the separate processors posited by this model.

2.4.1 Level One: Reflexive Interaction

What is a reflex? Well, it is some of the things that we commonly call by that name in spoken English, but the name is also often used incorrectly. Let us start our look at the model with a clear distinction between what is reflex and what is not.

When your foot snaps forward in response to a doctor stimulating your patellar ligament (with the edge of her hand or with a small rubber mallet), that movement is a reflex.

The patellar reflex is a commonly used example of a monosynaptic reflex arc, so-called because the stimulus sends an uninterrupted signal along a single synapse directly from the proprioceptor that detects the pressure to the motor neuron in the spinal cord that triggers the response.

In this type of reflex, detecting the input is the same as triggering the output. There are more complex reflexes, but this is one of many that you use almost constantly when walking, running, or trying to stand still. In fact, this reflex also triggers another, coordinated, and nearly simultaneous reflex that makes the opposing muscles in the hamstring relax. If you think about it for a moment, that coordination makes perfect sense, even though you may never have heard that additional information before. Most things are like that, aren't they: more complex than they might seem at first?

Well, it is the same with reflexes. They are triggered automatically, and you respond without any thought at all. All of the processing happens in the nerves. Multiple reflexive responses can be coordinated in the spinal cord, like in the example of the patellar reflex, where coordination happens in the spinal gray matter near the fourth lumbar vertebra.

It is also possible that reflexes can be coordinated at a "higher" level. The complex patterns of movement that turn repeatedly nearly falling forward into running are coordinated in the cerebellum. Here, one can develop physical skills as learned patterns of reflex coordination. These learned patterns are not to be confused with reflexes, in that they are not simple electrobiochemical responses to stimuli. Their coordination deteriorates with a lack of use. For the purposes of our model, all of these reflex areas (from the nerve endings just beneath the skin and deeply embedded in our organs to the gray matter of the pons and medulla oblongata[6]) are grouped with the cerebellum as a single processing system. This is

[6]Pons and medulla oblongata = parts of the brain stem linking the rest of the brain to the spinal cord.

the most primitive and the fastest of our natural systems for perceiving, processing, and responding to stimuli. For simplicity, we refer to it as "reflexive interaction."

2.4.2 Level Two: Reactive Interaction

When you respond angrily to a criticism of your favorite song, movie star, Web site, novel, religion, or scientist, you might say that the response is reflexive. You might say that, but you would be wrong.

If you really do not like snakes, or lizards, or puppies, and seeing one makes you feel icky, you might say that your response is just a reflex due to childhood trauma or a horrible accident in a psychology laboratory. You might say that, but you would be wrong.

Unless the response is actually rooted in a reflex arc of the sort described earlier, it is not a reflex. Now, you may feel that you had little or no conscious control of your response, and that may be right, but that does not make it a reflex, it just means that you were not consciously in control of your behavior. Let us take a closer look at what that means and how it can be.

When you are riding a bicycle, the coordination of your actions is the result of coordinated reflexes. The same kind of proprioceptive reflexes that allow you to stand upright also help you maintain your balance on two wheels. The same kind of learned patterns of coordination that allow you to establish and improve your skill as a runner also help you to establish and improve your skills as a cyclist.

On the other hand, at the same time that you are maintaining your balance and riding the bicycle on your chosen path, you are also perceiving the path itself and the still and moving obstacles to your intent. The patterns of relative movement of these obstacles tell you a lot about the conditions of the path and the speed at which you should proceed. These patterns are being compared with familiar patterns in a different part of your brain. This is where the familiar runs up against the unfamiliar. It is where you can quickly respond to the familiar and where you may try to fit new experiences into old categories. In fact, it is the same general region of the brain in which your emotional responses are processed. According to my model, this explains why so many of our fast pattern recognition thoughts become emotionally reinforced, even when there is nothing emotional about them, for instance, your irrational fear of other people's pets or your irrational love of Hedy Lamarr.

Of course, you can probably justify your fear, and Hedy Lamarr was both a great actress and a brilliant inventor… but you can't really trust rationalizations that you have invented to justify your emotional opinions. These justifications are not based on logic, but are facile and rapid emotional attempts to avoid the cognitive dissonance that would come with having to admit that we have done or believed something irrational (Festinger 1962).

This means that the rational part of our brain plays no role in our fastest decisions, but that we feel emotionally attached to the opinions we form in that manner.

It is understood in psychology that we all tend to create a perpetual fog of self-delusion in which our every past decision is justified, using new information and self-deception to convince ourselves that we have made wise decisions, even in the face of overwhelmingly contradictory evidence. This does not happen at a conscious level. It is like change blindness (Rayner 1978)—it is a pattern of accepting an overly simplified interpretation of the information we perceive and then defending the effects it has on our perception of the world. We apply our reason to justifying the reactive decisions we have made. This may be the root of our feelings of intuition and even of religious faith. As Steven Pinker explains:

> I will suggest that religion and philosophy are in part the application of mental tools to problems they were not designed to solve (Pinker 1997).

The rational resources of our brain can do more than compare and recognize, and they can also postulate, analyze, and form new ideas. This is the kind of processing we call "Reflective" or "Attentive." I have an informal postulate that we defend old patterns of knowledge emotionally, rather than rationally, in order to avoid having to reflect on them simply because reflection takes more energy. It might also explain why the surprises which should tell us we are about to have the chance to learn something new (Helson 1964) seem so often to trigger defensive emotional reactions rather than intellectual curiosity and eager anticipation (Jacobs et al. 2014).

2.4.3 Level Three: Reflective, Attentive, and Interaction

The highest and most evolutionarily modern level of our three-tiered hierarchy is the "Attentive" level of deliberate rational thought, or ratiocination, which we call "Reflective." This is the part of your brain that is reading these words and—I hope—considering their meaning.

Imagine two different ways of reading this chapter.

In the first case, you are feeling increasingly tired or bored. You are no longer giving the letters, words, and phrases your attention. Your eyes are still tracking along the lines and down the page according to learned reflex patterns, but your reflective thoughts have stopped following along. You lost "attentional focus" (Mesulam 1981). You catch yourself drifting off and realize that you have been reading without really *reading*.

In the second case, you are feeling interested and maybe even inspired, and the writing is leading you easily along a winding path from one idea to the next. In this second example, you are following the words and the ideas behind them; you are being "Reflective" and staying in what we call the "Attentive" level.

2.4.4 *The Three Levels Cooperating… and Sometimes Conflicting*

This hierarchy reflects the degree of to which we are consciously aware of what we are doing, but it also reflects (inversely) the degree to which we are consciously in control. Consider it like a lop-sided, non-cyclical version of rock–paper–scissors. Reflexive responses overpower reactive responses, even while reactive responses overpower reflective responses.

Not convinced? Make yourself blink. Now, stop yourself from blinking. Is it working? Keep trying while you turn your head quickly and stare at something far to the left of the room you are in. Did you blink? If not, you have successfully resisted an evolutionarily beneficial reflex and probably feel rather dizzy.

For another example, try to sneeze or hiccup through force of will. In most of us, these are reflexive actions, and it is not possible to directly control them. You can take snuff in order to trigger the sneeze reflex, but most of us have never even considered taking the time to learn to mentally trigger a sneeze.

But we do learn how to do things, and as we do, they move outward to different tiers. A toddler learning to walk must attentively coordinate the neuromuscular response to signals from the proprioceptors in feet, legs, hips, and spine in order to stand without falling. In fact, in early days, the more experienced shoulders, arms, and hands are also involved—waving in fast, asymmetric circles to help with balance. Soon, the recognition, processing, and response to these signals move from attentive control to pre-attentive, and you can see a toddler extend her left arm and leg simultaneously to try to keep from falling to the right. After a time, the process is fine-tuned and becomes purely a matter of coordinating reflexive responses.

With enough practice, we learn to add other deliberate tasks that we can perform simultaneously: balancing a full bowl of soup, for example, or carrying on a conversation. But the reflexive actions of walking supersede the reflective actions of walking while talking, or walking while balancing soup. If you stumble, the self-correcting reflexes that keep you on your feet prevent you from falling but interrupt your conversation and fling the soup across the room.

2.5 Peripheral Interaction: Unseen, and Crescive, and Ubiquitous—*A Brief Examination of the Fact that You Are Currently Interacting More Peripherally Than Deliberately, and an Argument for Why You Should Try to Stay that Way*

So, you are currently responding to countless reflexive stimuli that allow you to sit upright and breathe, etc, and you are currently responding to countless reactive stimuli that allow you to read and turn pages either electronically or on paper, all without any conscious recognition or disruption of the reflective attentional processes you are following in order to interpret these words as ideas. From an evolutionary perspective, this is exactly how your three parallel systems should work together—separate systems working at the same time. But there must be an additional mechanism—the ability to deliberately shift focused reflective processing away from one object and, at least temporarily, onto another. This natural ability was described by Weiser as a prerequisite of Calm, but he offered no mechanism to explain it (Weiser and Brown 1996).

In the ABC theory, this behavior is called DEF, and it is considered a key to our development of language and tools (Brown 2016). The interested reader should look to the references for a detailed explanation, but a simple one is offered here. The nesting habits of our protoprosimian ancestors might have allowed them the luxury of not having to always be on guard. Those on the inside of the pack could count on those on the outside to provide alarms when needed—either deliberately by screaming, or unintentionally by running off. Those on the inside, then, would have been free to be less vigilant and turn their senses to other activities. In the tight cluster, they could socialize by nattering and grooming. This could have led to additional social bonding and would have rewarded the ability to shift one's focus from that proximate and attentive task whenever peripheral sensory information gave hint of danger and to shift back again so as to maintain the relationship.

I have usually chosen to use examples from our ancestral line to illustrate the three tiers of processing described in my model (Brown 2013a). This is because I believe that their brain structure led them to perform daily routine activities in much the same way that we do now. That is to say that they divide their efforts between (a) what they want to do and (b) those things that they must do in order to be able to accomplish (a).

My use of anthropology-based examples has occasionally come under some criticism from computer scientists and psychologists who claim not to have any clear preconception of just how a protoprosimian would act in any situation whatsoever and, worse, who insist that I should not have any such preconceptions either. In response, we will now leave our protoprosimian ancestors to their grooming and turn to something (almost) completely different.

Imagine, if you will, a slimy, emaciated creature who might look a little like a skinny frog or a four-limbed spider, but with eyes like shining lamps. He is sitting in his cave and holding something very precious to him. He is concentrating both his stare and his attention on this precious thing clutched in his hands (Fig. 2.4a). Even if his attention is diverted to something else (along with his gaze), he remains at least partially attentive to his precious possession (Fig. 2.4b). This is in line with older theories of attentional focus which can be divided to some degree for some length of time.

Our model allows us to consider a more complex division of his attention, one that includes PI. Imagine the same character composing a reply to a new post on social media (Fig. 2.5). Here, we can see that, while his attention may be wandering in a way which belies the fixedness of his gaze, he is interacting unthinkingly with a keyboard, using it peripherally to serve his purpose, not as a purpose unto itself.

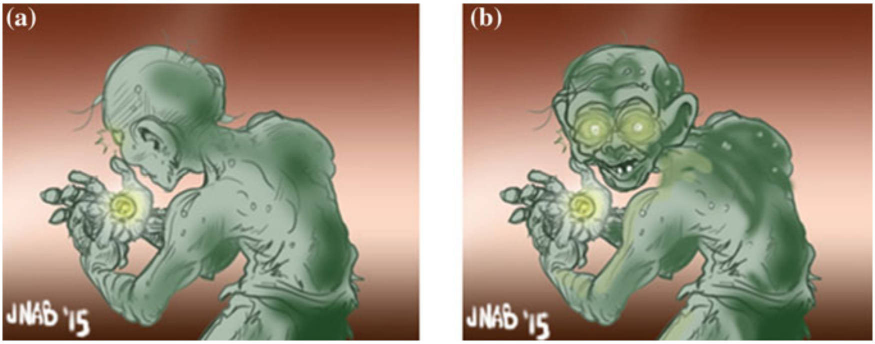

Fig. 2.4 **a** Focused attention and **b** divided attention

Fig. 2.5 Peripheral interaction with the keyboard and more!

This is, in fact, the very nature of a tool that we should be able to use it to accomplish something other than its use. Mark Weiser gave the example that once one puts on glasses, one should no longer have to pay attention to them (Weiser 1994). This is true of other well-designed or well-practiced tools and actions. A well-designed and well-maintained hammer should not require the conscious, reflective attention of the user under normal circumstances. One might use a hammer simply for the joy of using it, but the purpose of a hammer is usually the driving of nails or the performance of some other task, such as the breaking of rocks, the initiation of a patellar reflex in order to test nerve function between the L2 and L4 vertebrae, or the smiting of frost giants in order to protect Asgard.

This unthinking use of a tool is a fundamental example of PI. I believe that the same should be true of well-designed and well-maintained computerized technology. One reaches for one's mouse without looking and uses it to steer to and to select an icon, all without thinking of the mouse at all—unless something goes wrong. That would bring us back to the reverse-order imperative mentioned above, with the failure of the attempted PI would bring the tool to the center of our attention. Allow me to illustrate this.

Wanting to use the mouse, one reaches unthinkingly for where it should be, grasps it, and slides it in a manner that should move our cursor. We are not cognizant of the reaching and grasping and movement of the mouse, only of the attempt to move the cursor. The cursor is expected to behave as a natural extension of the human, so all of that is done at first-level attention—somewhere in the realm of learned patterns of reflexes (muscle memory) that we execute unthinkingly.

When the cursor fails to move, one's second-level attention is drawn to the failure and a pattern from early training is initiated. We repeat a smaller and faster version of the movement, or lift the mouse and put it back down again, or both of the above. Here, we are pre-attentively checking the mechanics of our attempt and unconsciously running through an iterative cycle that tries to answer the question: Is there a problem with how I am using this tool? When these simple tests still fail to make the cursor move, our full reflective attention is drawn away from the task and focused on the tool.

This is when we notice that we are trying to mouse with our smartphone.

Let us consider the smartphone a little more deeply in one final illustration of the application of our model to the understanding of PI.

2.6 Lost in the Flow: The Inherent Danger of Designing Ubiquitous Interactions to Be Immersive—*How We Might Use Our BRAINS to Avoid the Pitfalls of the Lack of Distraction*

According to a recent report from the World Health Organization, the leading cause of death among young adults worldwide is now the combined use of smartphones and automobiles (World Health Organization 2014). As has been remarked upon elsewhere, the shocking thing is not that there has been a worldwide response to this problem, but rather that the response is so obviously misdirected. In a total misunderstanding of the nature of human–machine interaction, manufacturers and lawmakers have focused almost universally not on prohibiting the use of smartphones while driving, and not on transforming the interface so that the interaction becomes less distracting, but on forcing drivers to interact with their devices in a "hands-free" manner (Caird et al. 2014). We have not had the time to evolve in response to the feeling of "Flow" brought on by technologically enhanced interaction. The illusion that we are somehow fully aware of our environment while totally immersed in some task may be what is killing us.

The key to the problem is that studies persist in treating the smartphone as a distraction. Unfortunately, distraction is only one of the roles played by this device and its ubiquitous relatives, the tablet, the palmtop, the smart watch and smart glasses, and most especially, the navigational assistant. We will return to the idea of the smartphone as a distraction and a disruption in the next section. For now, let us look at a much more dangerous aspect of the device: the fact that it is designed to pull the user into a state of immersive “Flow.”

Csikszentmihalyi’s work in this area is inspiring (MacLean 1973), as is his devotion to the promotion of positive psychology (Csikszentmihalyi and Csikszentmihalyi 2006). But let us examine his concept of “Flow” from the perspective of human factors, and through the lens of our new model.

The BRAINS model can account for the perception during “Flow” that the ego has fallen away and that conscious decisions are replaced by jazz-like improvisation and an intuitive belief that you are performing at the highest level of your skills.

Could it be that these feelings come from the fact that the most peripheral iterative feedback loops, the ones that naturally serve the purpose of keeping us aware of our environment, have here turned instead to providing more unconscious resources to the focus on the task? Consider the following aspects of working or playing in flow:

- You have a feeling of being more skilled—you are using more processing power, processors that are vastly faster (Tovée 1994).
- You feel deeply engaged in the task at hand—the resources in your system that evolved for the purpose of keeping you alive are now being used to perform tasks that are much more restricted in their scope and in their possible negative outcomes (Klasen et al. 2011).
- Time seems to disappear—the rational part of your brain, the part that tracks time’s passage, is not in use (Dennett and Kinsbourne 1992).
- You are no longer self-conscious—one might argue that you are not any sort of conscious. Your ego has disappeared—you are using resources that perform their tasks unconsciously—with your cognitive self literally left out of the loop (Carruthers 2014).

The beautiful fulfillment of being in “Flow” comes from the illusion that our peripheral sensors and processors are working smoothly and encountering only solvable problems. This is one of the ways that a game can feel just challenging enough to inspire the player to try harder. It fits into a natural feedback loop, one that rewards us for feeling that we are working well and safely.

But the feeling can be deceptive.

Exchanging a constant stream of shallow sms messages with one or more friends can give us the impression that we are successfully monitoring the world around us for danger. This feedback error will contribute to our learning the wrong reflexive and reactive patterns and create a self-deceptive illusion of attention and resultant safety. This may be why people are involved in accidents while texting. Not the distraction of having one's hands full, and not even the distraction of reflexive responses triggered by alerts and alarms, but rather the feeling of "Flow." The cause of all of these fatal accidents may be a side effect of the combination of unlimited communication and limited evolutionary pressures. As mentioned above, we have not had the time to evolve in response to the feeling of "Flow" brought on by technologically enhanced interaction. I propose that, rather than waiting for the violent resolution that natural selection will provide for this imbalance, we change the design of our interactive systems.

Incorporating the triune nature of the BRAINS model may enable HCI practitioners to deliberately infiltrate "Flow" without disrupting it during some situations and to interrupt it just as deliberately in others.

While deliberate human-to-device and device-to-human interaction during "Flow" has been clearly demonstrated, we are still trying to figure out how to provide important outside information to someone who is in "Flow." Traditionally, we attempt this through the use of blaring alarms, screaming ringtones, and other primitive concepts based on the observably false concept that if you scream at someone loudly enough, they will give you their full attention according to your schedule rather than their own.

2.7 ABC Ringtones: The Possibility of Alerts as Peripheral Information—*How We Might Apply Our BRAINS to a Practical Problem*

Traditional alerts and alarms are intended to draw our conscious attention, with the expectation that familiarization with our responsibilities and with the meaning of different alerts will allow us to make immediate rational decisions. In fact, as discussed above, such alerts stimulate a reflexive response and a reactive response that are much faster than any possible deliberate and reflective response. This means that our alarms and alerts should be designed with the expectation that they will trigger reflexes and reactions that supersede any reflective or deliberate response.

If this occurs at the wrong time, then the reflex and/or the reaction could interrupt an important rational process or preclude an important rational decision, or even a series of important decisions. For instance, let us take an example involving the limited-term, ongoing, and highly critical series of conscious decisions that allow someone to safely drive a car. You would not shout at a driver just as they are making a difficult turn, nor would you tickle the back of their neck. Coming at exactly the wrong moment, either of these distracting stimuli might result in an accident because the driver cannot consciously control their reflexive or reactive responses to those stimuli. The odds of there being an accident, and the odds of the accident being severe, increase in direct relation to speed and traffic density, and in inverse relation to familiarity with the route. Since navigational computers are designed specifically for use on unfamiliar routes, and since they are specifically designed to interrupt your ongoing thoughts and real-time decision-making processes, does it not seem as though they should be designed differently?

If so, then in what way(s) should the design be modified?

As mentioned above, the approach that is currently in favor is to move to hands-free interaction. Unfortunately, this does not address the issue of interruption at all. Let us look at it in the three different levels proposed by our model.

2.7.1 Interruption of Reflective Processing

The sudden arrival of an instruction to "turn left in 270 m" will still interrupt the driver's thought processes, and the nature of the instruction itself will still prove confusing, disrupting the driver's ability to navigate. What if there are three exits ahead, one after the other? Which one is 270 m away from where you were when the machine gave you your directions?

2.7.2 Interruption of Reactive Processing

The reactive system will also respond to the sudden announcement of directions, and it will do so faster than the reflective system. The triggered reaction will be based on well-established patterns of behavior. With the right deliberate preparation, the driver may have learned to ignore the sounds and wait for a reflective response, but how many drivers practice reacting to their navigational assistants before using them? It is more likely that an "intuitive" reaction will take place, based on the more established mental model of interacting with another human (Nass and Moon 2000). So, an experienced driver may hunch their shoulders or give some other unspoken sign that they do not want to be interrupted, while a less experienced driver might turn and glare at the machine, or tell it to be quiet—either one of which detracts from their performance by initiating a pattern recognition sequence that has nothing to do with driving.

2.7.3 Interruption of Reflexive Processing

The greatest danger lies in the interruption of reflexive processing, because this will happen so quickly that no other system can intervene. An unexpected noise may trigger a startled reaction in the driver, which can involve large muscle spasms—a dangerous thing when one is holding a steering wheel or gently applying pressure to an accelerator. That is for an unexpected noise. An expected noise may be even worse. What if the driver reacts to the noise according to a mental model of a more common irritating device, like an alarm clock? What if, in the "flow" of driving, the driver reflexively reaches for the device to turn it off? In a worst-case scenario, the driver becomes involved in this interaction for more than one cycle, moving it from the periphery to the center of their attention. They are now lost in the flow of interacting with the navigator, rather than with the car or the road or the rest of traffic.

Does that seem implausible to you? Consider the case of the pilots who got lost in their new vacation-scheduling software and flew 70 minutes past their target city while ignoring radio messages, fighter jets that had been sent to assess the possibility of a terrorist threat, and the flight attendants pounding on the door of the cabin (National Transportation Safety Board 2009; Brown 2012). This is just one extreme example of a very common event. As mentioned before, this kind of interactive problem is now seen as the primary cause of death among teens and young adults (World Health Organization 2014).

This issue reflects a well-documented, well-understood problem in tool design. Interaction suited to machine capabilities rather than human capabilities seems to persist wherever engineers are allowed to ignore human factors (Vicente 2003). Bardzell and Bardzell have proposed that this is due to the fact that it is easier to quantify machine factors (Bardzell and Bardzell 2014). In 2012, I posited that it should be possible to use the CPE to design alerts and alarms that inform us without interrupting us (Brown 2012). The idea is that

1. since the human brain is capable of filtering out "signal" from "noise," even when the noise is very loud, and
2. since the signal can then be understood without interrupting the ongoing actions or thoughts of the person for whom it is meaningful, then
3. it should be possible to build these features into deliberate computer output.

In 2014, a team working in Lisbon measured the effect of affective ringtones, that is, ringtones based on the ABC theory and the CPE. Though only preliminary data have been published so far (Brown 2016; Brown et al. 2015), the experiment clearly showed that it is possible to design alerts that will inform the intended recipient without disrupting their concentrated focus on another, deliberate task.

Figure 2.6 shows beta-wave activity[7] during the performance of a familiar but challenging task in a noisy environment, before and during the loud ringing of a

[7]Beta-wave activity = electrical activity between 12.5 and 30 Hz, a range of frequency commonly used in studies of the natural electrical activity in the brain.

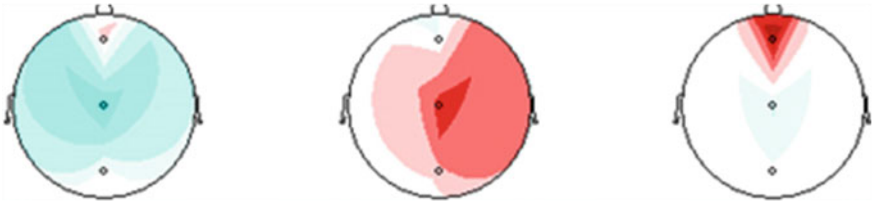

Fig. 2.6 Beta-wave density as measured with 5-point EEG—a loud unknown ringtone caused an increase in activity that persisted after the ringtone stopped

Fig. 2.7 Changes to beta-wave density when a loved one speaks your name too softly for you to consciously hear it

stranger's phone. Note the increase in activity in the prefrontal cortex[8] when the noise interrupts the participant's work.

Let us relate all of this brain activity back to our model. In a noisy environment, the reflective system is focused on a task. The reactive and reflexive systems are assisting in the performance of this task. Because you are focused on completing this task quickly and accurately, you ignore your own ringtone when you hear it, as you have learned to ignore other noises so that you can focus on your work. That said some noises are too soft to hear, while other noises catch your attention and interrupt your work. A stranger saying unimportant words is ignored at most volumes, as are most ringtones at most volumes. An unimportant word spoken by someone you love sometimes triggers a response, but sometimes does not.

ABC ringtones are different. When your name is spoken softly by the voice of someone you love—even if it is spoken too softly for you to consciously be able to react to it—some pre-attentive part of your brain reacts. As shown in in Fig. 2.7, there is a surge of activity in your reactive brain but no surge in your prefrontal cortex to interrupt focused work. Despite that, all participants reported hearing the ringtone. Without any interruption of your focus on the primary task, you are internally informed of the peripherally delivered information that your loved one has spoken your name.

[8]Prefrontal cortex = the front-most part of the neocortex—the crumpled up, six-layered brain hat we wear under our skulls.

The alert has not been delivered by a loud noise that demands attention; instead, it seems to have quietly triggered an internal information process. It seems as though the ABC ringtone can "…move easily from the periphery of our attention, to the center, and back" (Weiser and Brown 1996).

2.8 Conclusion: How Peripheral Interaction Has Remained Both Unseen and Crescive—*Gathering the Threads that Have Unfurled in Our Discussion and Attempting to Tie Their Fibers into a Knot upon Which the Reader Might Attempt to Climb to New Heights*

This chapter started with the simple statement that PI does exist. I have attempted to show that we all make use of it all of the time. I hope that the theory of ABC and the BRAINS model has helped to explain how PI happens. I also hope that the discussion of the ABC Ringtones Project in Lisbon has shown that it is possible to design human–computer interaction that makes good use of the natural qualities of PI.

Before concluding this chapter, let us have a quick review. To describe natural multitasking, task-switching, and the three very different speeds and qualities of human response to outside stimuli, I have proposed the BRAINS model, which has three hierarchical levels of processing. The first two happen unconsciously.

- The first fundamental level of processing deals with bodily functions. Aristotle called this the vegetative level, because even plants have some version of this. We include all of the simple, iterative reflex cycles—from the monosynaptic patellar reflex to the complex patterns of coordinated reflexes that let us breathe, shuffle playing cards, knit, or ride a bicycle—and we call it *reflexive*.
- At the second level, we do seem to think, but it is irrational and "intuitive" and often very emotional. This level addresses our desires with reactions that are too fast for conscious thought. The second is the level at which we respond to (internal or external) stimuli based on familiarity according to well-established patterns that are too complex for reflexive responses. Addressing primarily the desires and passions mediated at this level, Aristotle called this the appetitive level. Primarily addressing the speed and lack of consideration, we call it *reactive*.
- The third level is conscious. This is the level at which we use our intellect, our logic, and our ability to think formally. We call it *reflective*. Aristotle called this the rational or contemplative level and placed it at the top of Plato's hierarchy, saying it could take control of the other two. Many theorists continue to place it at the top of these interactive systems, in terms of both importance and control. From an ABC perspective, since this third processing system is the slowest and

> the most expensive to the body's metabolism, it is the system that is used the least. In the BRAINS model, based on observations that reflexes supplant reactions, and reactions supplant reflection, we place this system at the bottom of the hierarchy.

It is important to consider that only the reflexive system can sense anything, and its limitations shape all of our understanding of the real, material world. The data that do get through must then pass through the filters and reconstructions of the reactive processing system and its emotional and self-serving distortions in order to reach our reflective processing system.

In other words, human perception is like an unending game of "broken telephone" in which the illogical players can process information at 10 or 100 or 1000 times the speed of the slow-thinking intellectual who is last in line. We best use those processors to interact with the vast field of peripheral information that surrounds us in the natural world. If they deal with that information, then we do not have to process it all slowly and deliberately.

On the other hand, those faster reflexive and reactive processors sometimes supplant our reflective process, taking actions that were not thought out and then, upon reflection, finding means to justify those actions, resulting in self-delusion and cognitive dissonance.

This tendency is precisely why we must design our interactions to suit specific processors. Fast answers will always be based on established patterns of reflexes or of reactions—they will only be logical if the logical decision was determined and ingrained ahead of time. I have tried to show the dangers involved in our misunderstanding of how very ubiquitous PI is in our daily lives and especially in our interactions with computerized technology. I have also tried to offer up some information for the reader on a recent advance in the application of PI to the design of HCI.

I believe that our ABC ringtones will make phones less annoying by allowing everyone to hear their phone ring even though the volume is too low to be noticed by anyone else. The same style of alert could inform a driver of navigational instructions or of an incoming text message in a way that does not disrupt their attentive focus.

I also believe that ABC ringtones could point the way to designing alarms that will always penetrate to the conscious and reflective mind—even in situations where that has not proven possible to date. For example, let us reconsider those pilots who got immersed in their software and lost track of time. When the air traffic controllers, the air force, and even the cabin crew were unable to get the attention of the pilots, maybe an ABC alert would have worked. What if they had each received customized messages—the voice of a loved one saying "why aren't you answering the radio?"

There could be other applications. Elsewhere, I have discussed the possibility of creating a formal system to help police who might otherwise get lost in a negative feedback loop of fear and preparedness that could lead to an unwarranted shooting

(Brown 2015c). The unconscious iterative feedback cycle could be interrupted by the voice of a loved one reminding them to slow down and consider their options.

Imagine a firefighter who must receive important new information about the structural integrity of the building they are in. Flashing lights and loud noises are of no use there, but what if the firefighter were to suddenly hear the voice of his daughter? In the same way, a soldier lost in the "fog of war" could be reminded of her role and responsibilities by hearing the voice of her distant lover.

To conclude, you are engaged in PI right now. Once, you had to focus on each letter in order to be able to read, and you had to work to improve. The improvements became crescive and the use of letters became peripheral, and in time, you were able to focus on the message rather than on its acquisition. What's more, every deliberate task that you learn to perform with fluency will also become peripheral in time. It is our responsibility to design tools that suit and even take advantage of the unseen and crescive processes of our ubiquitous PI.

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