The enduring basis of emotional episodes:
Towards a capacious overview

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Abstract—It matters for affective computing to have a framework that brings key points about human emotion to mind in an orderly way. A natural option builds on the ancient view that overt emotion arises from interactions between rational awareness and systems of a different type whose functions are ongoing, but not obvious. Key ideas from modern research can be incorporated by assuming that the latter do five broad kinds of work: evaluating states of affairs; preparing us to act accordingly; learning from significant conjunctions; interrupting conscious processes if need be; and aligning us with other people. Multiple structures act as interfaces between those systems and rational awareness. Emotional feelings inform conscious awareness of what they are doing, and emotion words split the space of their activity into discrete regions. The picture is not ideal, but it offers a substantial organising device.

Keywords—emotion; evaluation; learning; interrupt; feelings

I. INTRODUCTION

There is an increasingly robust body of computational research dealing with emotion or affect, but it conspicuously does not have a robust way of summing up what it is about – emotion or affect. Recent handbooks illustrate the point [1,2,3]. They provide illuminating reviews of contrasting theories, but much less in the way of convergence on a working understanding. It is revealing that probably the most extensive integration, due to Scherer, is presented as a framework in which to set competing models [4].

There are good reasons for the caution. The writers are mostly psychologists, and professionally bound to be wary of claims that go beyond the data, or violate parsimony. However, the pressures for affective computing are not quite the same. There, it matters to have a framework that brings relevant issues to mind in an orderly way.

The point is not to have a masterplan for a program that simulates human emotional makeup in its entirety – that is not realistic now, if it ever will be. It is to have an image, in the broad, intuitive sense of the word, of the systems that programs will interact with. One assumes that people building a robot to land on a comet recognise the need to have a working description of the comet to hand. That is not the same as having a myriad of technical papers, from which one can pick fascinating details, like Aladdin in his cave. It is something that ensures the essentials are hard to miss.

It is hard to see how affective computing can do without something of the sort, for two broad kinds of reason. The first is pragmatic. The systems that they have to interact with are complicated; and if system-building is guided by a selective image of them, there is an obvious risk that features the builders ignored will come into play. The second is ethical. With a human being as with a unique comet, there are some kinds of damage that must not be done. A third is speculative, but worth mentioning. Nobody should expect a masterplan, but a wide-ranging picture may be a useful stimulus to technical development.

The idea behind this paper is that if that is the goal, then there is a natural way of bringing together many of the most powerful ideas about emotion in the literature.

Most of the ideas in question have been offered as proposals about the essential nature of emotion. The strategy here involves accepting that all of them point to something that is essential to emotion, but none of them is the essence. They all point to essential parts of a larger whole.

The way they are brought together achieves at least a degree of coherence, in three ways. It sets elements in the context of an ancient framework, due to Plato [5]. It prioritises the same kind of question about all of them, which is the kind of work that they do. It also separates them into a core of elements associated with underlying systems, and a second layer associated with the interaction between them and (roughly) rational functions. Theoretically, the scheme begs for a deeper understanding of what the parts are, and how they relate to each other. But simply being able to put that range of significant ideas into a common format makes it an organising device worth having.

II. Plato’s Framework

Efforts to integrate ideas depend heavily on prior assumptions about scale and complexity. Some images of emotion imply that it is both logically and temporally restricted: a short-lived state centred on a distinctive, unanalysable kind of experience. Starting with that kind of image makes it very difficult to imagine how emotion could have all the various qualities that are attributed to it.

At the other extreme is an image due to Plato [5]. It locates episodes dominated by emotion within a much larger picture, involving a particular form of interaction between two substantial systems. One, which we are continually aware of, is essentially rational, and usually in control: the other is always at work, but usually unnoticed. Strong emotion occurs when...
the second system overtures rational control and asserts itself. Developing that kind of framework involves elaborating pictures of the second system, and that provides much more space to imagine how various combinations of properties might come into play.

The freedom is not uncontroversial. Postulating processes that are mind-like, but not accessible to consciousness, cuts against the long-established warning not to multiply entities unnecessarily; and experience has made psychology doubly wary of it [6]. That favours emphasis on phenomena that clearly are part of experience – intense, transient feelings; the actions that go with them; and the words that describe them. Nevertheless, moving towards Plato is not unreasonable.

Experience does suggest that elements akin to overt emotion are an ongoing part of mental life. It was observed long ago that a distinctive emotional colouring is an enduring part of the meaning of a word [7]. More recent studies show that people rarely report being completely unemotional when they are asked to report their state at random times [8], or judge that others are unemotional when they watch them over long periods [9]. Something akin to emotion is pervasive [10], and parsimony actually favours assuming that the same mechanisms underlie both salient bursts of emotion and their pervasive kin.

It is a non-trivial issue that naming the hypothetical systems presents problems. Rational awareness is an obvious term for the system that usually exerts control. Plato called the other *thumos*. That has specific implications that raise problems, but the term points in a useful direction. Its root implies swift, fluent movement. The sense that emotion has a fluid quality is very widespread – it is described as overflowing or surging or sweeping us along or being stirred up or draining away. Computationally, it is an interesting metaphor to bear in mind.

Looking at other possible terms raises a point which is important both here and later. In some areas, it is fair to assume that word meanings reveal boundaries that are deeply grounded in nature, and research should be guided by them [11]. The theory suggests that here, that may not be so. Words are instruments of rational awareness, and if that system knows rather little about the others, it may struggle to find words for them. In fact, word meanings in the area have been unstable in ways which fit that. *Thumos* suited Plato because it could refer either to a transient state (righteous anger) or an enduring part of us (‘spirit’, as in ‘spirited’). Another Greek word, *patheia*, primarily meant a state, one inflicted on the person: but it could involve emotion or illness. Latin created counterparts: *passio*, by sound imitation, and *adfectio*, meaning ‘done to’. From those descended ‘passions’ and ‘affect’. In philosophy, ‘passions’ came to denote potent, enduring attachments to certain things [12]. ‘Affect’ was adopted later to mean feeling; partly because ‘sentiment’, from the Latin for feeling (*sentire*) had come to mean specifically ineffectual feeling. Latin also used *perturbatio*, which implied motion. So initially did ‘emotion’: but it shifted to have a broader meaning.

That history is consistent with an area where it is not apparent to rational awareness what the key boundaries are. If so, research should beware of expecting any current word to denote an appropriate field of study. On that basis, ‘affective systems’ seems a reasonable working description of what we want to study, particularly if it is used with the Latin in mind, to signify systems that ‘do something’ to rational awareness.

III. CORE TASKS OF AFFECTIVE SYSTEMS

Scherer’s framework, mentioned earlier, identifies three main tasks for the systems underlying emotion: evaluation, preparation, and communication. There are large literatures on all three. Two others are identified as central in other literatures. One is a reinforcing function, which is fundamental to learning; the other is interrupting processes under rational control under some circumstances. This section picks out key points and references for each.

A. Evaluation

Magda Arnold [13] introduced the concept of appraisal to describe specialised evaluation processes concerned with our ‘weal or woe’, and leading to specialised preparations rather than general awareness. It is very widely known in computational research. A development of the idea which integrates with other areas, also due to Scherer [14], divides appraisal into five broad levels:

- **Novelty**, i.e. whether there is something in our surroundings that it might matter to know more about.
- **Pleasantness**, i.e. the sense that things or situations are fundamentally positive or negative – which is fundamental, but notoriously difficult to analyse.
- **Goal significance** considers whether something serves or obstructs our purposes, rather than its intrinsic value.
- **Coping potential** considers our ability to make use of the opportunities it offers, or deal with the threats.
- **Normative significance** deals with its relationship to standards, our own or other people’s. The classical example is that embarrassment is what happens when an action violates standards that other people hold; shame is what happens when it violates our own.

Scherer’s list of checks lends itself to an integrated account partly because it separates criteria for evaluation from other issues – notably, what is evaluated, and whether the evaluation leads to a distinctive emotional state. The term ‘appraisal’ is sometimes linked to those issues – implying that the thing evaluated is physically present and/or the result is a distinctive state. That makes it useful to keep ‘evaluation’ as a more general heading.

B. Directing Evaluation

Both classically [12] and recently [15], philosophical conceptions of emotion have emphasised that there is something it is about – an ‘object’. That sits uneasily with paradigms that appear to treat emotion as a quantity or set of quantities to be measured – adapting a metaphor from Augustine, wave height and cloud cover in the mind. Recently, interest in context has brought a shift of emphasis, so that the task of understanding emotion is more often taken to include
identifying something that it is about. However, another kind of extension should be set alongside that.

It is tempting to assume that the relevant kind of object will be of the kind that James portrayed in his famous example, a bear appearing suddenly in the woods [16]. However, it is crucial that the objects may be extraordinarily varied. That is central to one of the best known appraisal schemes, ‘OCC’ [17]. It does not integrate into the scheme being developed here, but Scherer’s scheme can be adapted to make the point.

Scherer’s novelty check can be understood as a special case of a general function, identifying potentially significant states of affairs: directing evaluation, for short. The bear in the woods is the simplest case – compact, and physically present. However, it is not the only case.

Even in James’ story, another candidate deserves attention: the woods themselves. Responses to global settings – landscapes – are powerful, and little understood [18]. Beyond landscapes, mindscapes contain a huge variety of potential objects. They include things, people, states, actions (intentional or otherwise); past, future, elsewhere, or fictional; and relations between the subject and those objects. The OCC scheme points out that those distinctions are embedded in emotion language.

The fact that affective systems can search a huge space of candidates for appraisal is fundamental to them, and not well understood. Goldie evoked dramatically the way multiple objects can crowd to mind and fade [19]. More practical studies illustrate why the issue matters computationally. The expressions of a person talking about events in the past shift very rapidly as different aspects come to mind, and the focus shifts between them and the interlocutor [20]. When people smile during the narration of terrible events, it is likely to reflect their appraisal of the hearer, or the interview situation, not the events. Registering that automatically raises major challenges, but it matters: it would be a travesty if a system logged a smile at the interviewer as evidence that the speaker was happy with the situation.

C. Preparation

Preparation is intrinsically linked to the evaluations that we attribute to affective systems. There are purely cognitive evaluations – evaluations of alternative algorithms in a program may be an example. At least one key contrast between those and affective evaluations is that the affective evaluations automatically entrain various kinds of preparation to deal with the state of affairs as they assess it. A brief sketch suggests the range of preparations that affective systems initiate. It is truly striking, and it one of the main reasons why they matter.

A well-known family of preparations involves the balance between sympathetic and parasympathetic branches of the autonomic nervous system. Common descriptions of the two, ‘fight or flight’, and ‘rest and digest’, suggest that the changes may have been preparations in the environments where humans evolved; but in modern cities, they are dysfunctional. That is true of some aspects: it seems that the function of eccrine sweat on the palms and soles of the feet was to facilitate rapid escape by swinging through the trees. In fact, though, the two branches adjust quite flexibly and specifically to anticipate demands for energy, digestive enzymes, etc., within the normal range [21].

A second kind of preparation is implicit in Aristotle’s famous definition of anger as “an impulse, accompanied by pain, to a conspicuous revenge…” [22]. An influential modern theory of emotion, due to Frijda [23], highlighted a concept akin to impulse; that is, action readiness. Frijda argued that the differences between emotions lay in the different kind of action for which they readied people, and the idea that action readiness is fundamental to emotion is widely accepted.

Preparations that are less visible to intuition involve various hormones and neurotransmitters. Choosing a goal and achieving it releases dopamine, and facilitates learning from the experience [24]. Warm relationships release oxytocin, which increases disposition to engage with the other person – and deprivation of relationships lowers oxytocin levels, and disposes people to seek relationships [25]. Stress releases cortisol, associated with adjustments that conserve energy for essential tasks. It has long been said that one of them is lowered immune function: recent studies seem to be clarifying the mechanisms [26].

Adjustments in a final group are less often seen as preparation, although they clearly predispose cognition to lean in particular directions. The way we appraise the situation affects the things that come easily to memory. In a sad state, things that happened in previous sad states come easily to mind: and similarly for happiness [27]. That encourages conscious awareness to draw its lessons from situations like the current one. A similar pattern affects the present: the dominant appraisal prepares people to notice things that fit it. Being happy makes happy faces more likely to be noticed; feeling threatened does the same for threatening events [28].

Similarly, different appraisals change readiness to find out by exploring: happiness increases it, fear reduces it [29]. Fear primes sharp withdrawal at any unexpected stimulus – that is the startle reflex [30]. It also reduces readiness to engage in processing that takes time and mental resources – for instance making sense of a message that is at all complex [31]. Last but not least, appraisal shifts estimates of risk [32].

One of the attractions of a model like Plato’s is that it makes sense to imagine conscious awareness relying on various kinds of preparatory work, which limit the options that it has to deal with. That means that it provides a natural place for the diverse kinds of evidence that have been sketched in this section, which a satisfactory understanding of emotion clearly should do.

D. Learning

There is a significant tradition that sees learning as the central function of emotion, represented by Tomkins in the mid 20th century [33] and Rolls at the end of it [34]. It is grounded in conditioning, which is a singularly powerful form of learning. It takes two forms. Classical conditioning links two stimuli, so that one which was originally neutral takes on meaning that was originally attached to the other. Operant conditioning links a stimulus to a response, so that presenting the stimulus comes to elicit the response. In both cases,
learning depends on something that marks the link as important – it is called reinforcement.

Reinforcement is intimately bound up with emotion. In classical conditioning, what drives learning is discovering that both stimuli predict something that is emotionally significant – like food, in Pavlov’s original experiments. In operant conditioning, it is the fact that a particular sequence of stimulus and response produces an emotionally positive outcome. Hence Rolls recommends a definition of emotions as “states produced by instrumental reinforcing stimuli” (p. 61).

Once again, a Platonic framework allows us to give clear recognition to the fact that affective systems have important roles in kinds of learning. A particularly interesting point is that the learning affects the systems themselves. Things come to be appraised as aversive as a result of conditioning, and association with them can make other things aversive. Tomkins argued that that process builds ‘scripts’ which allow stimuli to elicit much stronger affective responses, and hence much more effective learning, than would otherwise occur. That is a significant line of argument against the idea that emotions are fixed by evolution.

The ethical literature seems not to have picked up the connection, but if a system can be used to manipulate emotions, then it can probably be used to achieve conditioning. That raises issues that are taken up in the section on the will, and which need to be treated with extreme sensitivity.

E. Interrupt

Identifying interrupt as one function among many is a far-reaching idea, and contrary to widespread intuitions. It is very easy to assume that ‘emotion’ and related words are about states that occasionally interrupt rational awareness, or try to, and that is all they do. Plato’s picture suggests otherwise. According to it, there are distinctive states that occur when rational awareness loses control, partly or wholly, but we will not understand them unless we recognise that what takes over is constantly doing other things, on which we rely.

The idea that interrupt itself is functional is another step. It was fundamental to a major debate in the ancient world. Stoics argued that interrupts were contrary to our true nature, which was rational; and we should learn to stop them from imposing pathieia and afectiones. Plato thought otherwise. For him, thumos sometimes propelled us on the right road when reason would hesitate.

The difference is partly a matter of values rather than facts. People have the right to opt for Stoic values, and some do. However, Oatley and Johnson-Laird have made an interesting case for seeing interrupt as a positive function [35]. It rests on the fallibility of the plans that rational awareness develops and follows. The bear in the woods is one case where they break down: we encounter something that the plan for a stroll did not anticipate. Intervention there has an obvious function. However, breakdowns can be subtler – particularly with large scale plans, for a lifestyle or enduring relationship. For Oatley and Johnson-Laird, emotion has a role in bringing us to recognise those breakdowns, dismantle the structures that have to be put aside, and build new ones.

It is important for affective computing where it places its goals in that range of possibilities. Some obvious applications are about detecting interrupts and preventing damage – ‘finding trouble in conversation’, as a classic paper put it [55]. Encouraging interrupts – be they happiness or cathartic sadness – raises different issues: Stoics would rarely approve. Some of their concerns can be dismissed as personal, but others raise issues linked to constructs like will, which are taken up shortly.

F. Alignment

Arguing against the Stoics, Augustine pointed to one manifestation of emotion that even they valued: compassion [36]. The link between emotion and communication was recognised even earlier (Aristotle’s definition of anger was for the benefit of rhetoricians), and some recent theorists see emotion as essentially social [37].

Interpersonal phenomena involving emotion are hugely diverse, from emotional contagion [38] and mimicry [39] to conditions where normal emotional connections are not made [40]. A useful way of conceptualising the central task is that it involves alignment [41]. Key aspects of people’s states are brought into a global relationship – which may mean convergence, complementarity, or a recognisable kind of divergence – that sets a framework where the intentions behind specific gestures can be understood.

It is not self-evident why emotion has that role: one might expect the framework for communication to be set by linguistic devices related to topic, floor management, and so on. That raises quite deep questions about mutual understanding.

In the context of a Platonic model, it is also striking that this is an area where affective systems routinely control action with very limited reference to rational awareness. Usually no interrupt is needed to let the impulse to smile translate into action. Attempts to generate the signals deliberately are structurally distinctive, and often associated with deception [42] – though not always [43]). Relative independence is facilitated by the existence of specialised channels – involving face, voice, posture, and manner of action – for encoding and decoding the relevant messages. From that perspective, shared channels – such as emotive words – become very interesting.

IV. INTERFACE CONSTRUCTS

It is basic to Plato’s framework that the channels of communication between rational awareness and affective systems are limited. Without that assumption, we could not justify a picture of complex systems whose work rational awareness knows relatively little about. However, it raises the issue of how the systems do interact with rational awareness.

For the purpose of providing an overview that is at least partly unified, it makes to think of the issues in terms of interface constructs – systems that are accessible in at least some ways to both rational awareness and affective systems. Four clearly deserve to be an integral part of a broad overview: will, desires, moral codes, and narratives. There are reasons why they should be of interest to affective computing, and literatures that offer interesting ideas about them.
A. **Will**

The concept of will has held a central place in discussions of the relationship between affect and reason, from Aristotle [44] to the modern era [55]. Adapting a definition from Descartes, will is what enables us to make a deliberate decision to do or not do something [50]. As such, one of its key functions is to ensure that we take the course of action that we have deliberately decided to, and are not swept away by impulses that urge us in a different direction. It is a function that takes mental effort, and that we may not be able to sustain. Aristotle describes various reasons why we may not, most interestingly *akrasia*, typically rendered as weakness of the will.

There are two obvious reasons why the concept of will should be embedded in affective computing, one practical and the other ethical.

The practical reason goes back to the issue of undesirable interrupts. If we are concerned with, for example, ‘trouble in conversation’, then the obvious time to intervene is not when a person has been overwhelmed by negative impulses. It is when only an exercise of will is preventing the speaker from terminating the interaction angrily.

There does not appear to be research on recognising the exercise of will. Logically, it would seem to be a natural part of affective computing, and it is an attractive topic.

The ethical reason is that the will has occupied a fundamental place in ethical systems from Aristotle’s on. For Kant in particular, exercising the will was at the heart of virtue. The converse is that there are enormous ethical problems associated with artificial systems that strengthen emotional impulses in a way that make it difficult for the will to resist. There is a sophisticated discussion of those issues [57]. The point here is that once we bring the will firmly into our picture of emotion, it becomes easy to see that they are issues to be concerned about.

B. **Desires**

The second structure also involves a familiar term for something very puzzling – that is, desire. The term is established in computing because of BDI models of thought – that stands for, belief, desire, intention [45]. The models involve reasoning-like processes. That assumes that a desire is the kind of thing that can enter into a reasoning process. That is credible, particularly if we accept that it is only one side of the coin.

The other side of the coin is that a desire resonates with affective systems – particularly positive evaluations and preparations aimed at gratifying them. That means it crystallises emotional patterns into a form that reason can work with.

As with will, thinking about the concept of desire points to obvious challenges. It seems to come across in interactions that some intentions are driven by desires grounded in affective systems, whereas others are simply because something is obvious, or expected. If so, then it would seem to be a real issue, most obviously for sentiment analysis. A different challenge is integrating emotional charge into reasoning processes. That raises issues, for instance around inconsistent emotions, which need careful exploration [58].

C. **Moral Codes**

The third structure involves a similarly two-sided coin. It involves moral codes. Like desires, moral codes are a form that reason can work with. The intuition that they shape emotion is reflected in Scherer’s account of appraisal, and has a long history: for Plato, sensitivity to moral values was a defining feature of *thumos*. Hume reversed the connection, suggesting that morality was grounded in passions. A natural balance is that moral codes need to be “motivationally effective”, and that requires “learning emotions and ethics in the same breath” [46]. At the very least, it is clearly the case that a person’s...
emotions may be mystifying unless one understands his or her moral codes; and the same for moral behaviour unless one understands how ‘motivationally effective’ explicit codes are.

D. Narratives

The last structure was highlighted by Goldie [47], drawing on evidence from therapies. He argued that unaanalysed experience leaves a residue of memories with powerful emotional charges, which can generate problems unless it is ordered. A key way of doing that was embedding it in narratives. They show how one thing followed from another, and why that is to be expected, and accepted.

A key point about building narratives in Goldie’s sense is that unlike building Tomkins’ scripts, it involves rational awareness as well as affective systems. Articulating issues is crucial to forming a narrative. Once achieved, it is a key to linking affective processes and rational awareness: it allows us to understand that if someone feels like this, it tends to be because something like that has happened; and it tends to lead in one of these directions.

The idea has a very direct link to affective computing. A number of high-profile programs (e.g. FearNot [48] and Carmen’s Bright Ideas [49]) are about helping people to build narratives that let them deal with difficult events. It matters that our explicit understanding of emotion aligns with the implicit sense that building potent narratives belongs fairly and squarely within the field.

The key point here is that there are interface constructs – structures that bring together emotional charge and cognitive content. It is not claimed that the ones mentioned here are the only ones: they are the cases that most obviously matter.

V. Awareness of Emotion

Quite deliberately, the discussion has covered a wide range of issues related to emotion without considering either of the two subjects that tend to dominate discussions of the subject – emotional feelings and emotion words. The point is that our understanding of emotion does not need to be organised around those issues. On the contrary, it is possible to build a picture that is both extensive and coherent (at least up to a point) without bringing them into focus. That is not an accident. Both emotion words, and still more emotional feelings, are elusive. It is easier to construct an ordered picture by focussing on something that can be expected to make sense – that is, the work done by affective systems.

The first area is feeling – or rather, the distinctive kind of feeling that we recognise as emotional. The approach here sets up a powerful way of looking at it. Feeling is another intermediate structure: a representation that lets conscious awareness register in a very imprecise way what is happening in systems that it neither fully controls, nor fully understands. The idea has long roots. Descartes thought emotional feelings were the mind being dominated by a commotion caused by physical reactions – involving the heart, ingredients of the blood, and so on [50]. William James saw them as the mind registering events roughly corresponding to action tendencies [16]. The effects of reducing bodily feedback suggest that there is truth in those ideas [51]. More recently, Clore and his colleagues argued that they were information derived from emotional evaluations of the situation that conscious awareness could use [52]: Forgas elaborated the model [53].

There is obviously much more to the story. Feelings may be a compressed representation of the multiple things that affective systems are doing, but the medium has some fascinating properties. There are robust simplifications [54], but listening to music suggests that there is much more: feelings of warmth or chill, light and darkness, tension and stability, planes tilting and sliding, vastness and pettiness. It seems to be a second language of awareness – one that is not native to rational thought, but that it can draw some key messages from.

That leads, finally, to the place where people tend to start, which is the system of categories that we use to talk about emotion – expressed in words like fear and anger and happiness. We should also include the word emotion itself, and its predecessors back to Plato’s thumos and pathēō.

The possible states of the affective systems, and the intermediate structures linked to them, define a space with a huge number of dimensions. Language has to divide it into discrete regions. As indicated at the beginning of this paper, the history of emotion language suggests that there is a deal of arbitrariness about the division – which is why it is a nightmare translating Plato into modern English.

Clearly machines need to deal with the words if they are to communicate with people; but that does not mean that the words are the heart of the matter, any more than feelings are. It makes sense to think of both as means of capturing at least some information about the complex flows and balances that take place in affective systems, in a format that is at least partly intelligible to conscious, language-oriented awareness.

VI. Conclusion

The core aim of this paper has been to offer an organising scheme – a structure that provides natural places for diverse kinds of idea that are relevant to affective computing, and the literatures that discuss them. For that purpose at least, it is useful to follow Plato’s lead, focusing first on the work done by systems about which rational awareness has relatively little direct knowledge: and using the framework that that provides to return to phenomena that are part of everyday experience, but by no means transparent.

Of course, people may want to argue for a different way of structuring the issues – perhaps taking emotion words, or pure feelings, as the starting point, and showing how other topics fall into place around them. It would be a useful contribution to generate an alternative scheme that could be compared with this one. The main concern is not to defend this scheme: it is to highlight the idea that developers should put work into forming images, in the broad, intuitive sense of the word, of the systems that their programs will interact with.

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