data I know of (apart from the infant data) are Kruschke's findings of reaction-time effects that suggest feature transfer in launch, but not control, events[33]. These results fit well with Michotte's 'ampliation' process for PC, but Kruschke points out that they do not help us to decide whether the percept is independent of interpretation. He also distinguishes underlying process and phenomenology, but takes the latter to be integral to perception. This accords both with intuition and standard definition.

Conclusion

The experience of PC would not appear to be encapsulated. Several processes potentially feed into it. Any one of these could be modular – a vestige of an innate process – but empirically the question remains open. I look forward to studies that address this. Such a module might be perception in an architectural sense, but not in the sense of everyday phenomenology: the data suggest a more complex relationship between process and phenomenology than a simple modular approach allows. It would be good if our theories could do justice to both.

As Scholl and Tremoulet state, PC is interesting because it lies at the interface of perception and cognition. I agree; moreover, I think PC has a dual nature. Focal attention, stressed by those authors, seems one promising way to disentangle this. Development, surely, is another.

Acknowledgements
This work was supported by ESRC grant R000237058.

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Seeing size and weight

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The remarkable accuracy and grace of human movement derives, in large part, from the ability to program motor output in an anticipatory manner. In the act of reaching for an object, visual information is used to estimate the amplitude of the reach, the orientation and size of the aperture required to grasp the object and the manipulative forces to be exerted for its efficient retrieval. In recent years, much research has been stimulated by the proposal that the visual analysis that guides goal-directed actions might be distinct from that giving rise to our conscious visual perception[1,2]. Milner and Goodale[2] have suggested that this functional distinction can be mapped onto the anatomical division between the dorsal (occipito-parietal) and ventral (occipito-temporal) pathways diverging from primary visual cortex. Compelling evidence for this view comes from patients with selective damage to one or other of these pathways. Occipito-temporal damage can cause profound deficits of visual awareness and object recognition whilst leaving visuomotor abilities largely intact[3]. Conversely, patients with occipito-parietal lesions may be able to describe the size, shape and disposition of objects, yet be unable to act skilfully towards them under visual guidance[4].

Perception–action dissociation with visual illusions?

It has been claimed that a similar dissociation between perception and action can be revealed in healthy subjects where pictorial cues are used to induce illusory misperceptions of the size (or location) of objects. Several authors have reported that action based responses are relatively immune to such illusions despite their powerful sway over conscious perception[5–7]. These reports are consistent with the proposal that vision for action should be unconcerned with global visual context and should instead be restricted to the pragmatically relevant properties of

 PII: S1364-6613(00)01556-4

objects (e.g. their shape, size and orientation, and their distance and direction from the body)[2]. However, as noted in a recent TICS *Update Monitor* piece[8], considerable controversy surrounds these findings. It has been argued that the reported dissociations between perceptual and motor responses to the Ebbinghaus size-contrast illusion and the Judd illusion can be fully explained by non-equivalences between the conditions under which the two types of responses were obtained[9–11] (but see Haffenden and Goodale for a recent rebuttal[12]).

Notwithstanding the debate over the use of visual illusions to study perception–action differences, a recent paper by Jackson and Shaw that uses this general strategy seems worthy of special consideration[13]. In an elaboration of an original study by Brenner and Smeets[14], Jackson and Shaw asked subjects to pick up cylinders of three sizes, presented against the converging or diverging ends of a pictorial background based on the Ponzo illusion. The maximum grip aperture attained and the peak grip force applied to the object were recorded. Both measures were sensitive to object size such that the hand opened wider for, and applied greater force to, larger objects. Peak grip force was additionally affected by the Ponzo background, with reliably larger forces being exerted on those (apparently larger) objects presented against the converging lines. Maximum grip aperture, by contrast, was uninfluenced by this manipulation. As both dependent measures were obtained from the same responses, these findings cannot be explained by differences between testing conditions. The results seem to indicate that different visual size estimates govern the anticipatory programming of grip aperture and grip force.

It should perhaps be noted that the relevant size cues for grip force and grip aperture are, to some extent, inherently different. Whilst an object's volume is needed to predict its weight, the size cue for precision grip is uni-dimensional, so illusions of three-dimensional size might be expected to have a more powerful influence on grip force than on grip aperture. It is difficult, however, to explain the complete absence of contextual effects on grip aperture on these grounds alone. Moreover, Jackson and Shaw's data are consistent with an earlier report that grip aperture is uninfluenced by the Ponzo illusion (though the illusion did affect an indirect measure of lift force)[14]. Even so, it might be desirable to attempt to replicate these findings under conditions where visual feedback from the hand is denied. Such a replication would eliminate the possible objection that the reported dissociation might reflect differences in the on-line use of visual feedback to adjust grip aperture and grip force.

Visual cues to object weight

Jackson and Shaw's experiment cuts across the perception–action dichotomy with which previous work in this area has been primarily concerned. Instead, their finding implies a dissociation between the visual processing of object size that regulates different aspects of visuomotor performance. Nonetheless, they interpreted this dissociation in terms of the division between dorsal and ventral visual processing. This inference was based partly on the assumption that only the ventral stream is prone to pictorial illusions. However, their interpretation was also informed by a consideration of the different kinds of information that are necessary for the programming of grip aperture and grip force respectively. An exclusively spatial analysis might be sufficient for a novel object to be grasped accurately, but for its weight to be predicted from its size, some estimate of its density is required. This necessitates that the object be identified, at least to the level of categorizing the substance of which it is composed. Because visual object recognition depends upon the integrity of the ventral stream[2], it seems reasonable to suggest that this pathway will be involved in processing the visual information on which an initial weight estimate is based.

We have collected preliminary data that strongly supports this idea (see note in Acknowledgements). The visual-form agnosic patient 'DF' (who has bilateral occipito-temporal damage) is severely impaired at perceptual size discrimination, although she scales her grip size normally when grasping. We presented her repeatedly with three objects of equal weight but markedly different sizes, which she lifted by means of a force transducer. In contrast to normal behaviour, DF's fingertip forces were unrelated to object size, even on the initial trials. The lack of influence of visual size on DF's force production suggests that these aspects of visuomotor control do indeed require ventral stream involvement.

Memory cues to object weight

A second aspect of Jackson and Shaw's data also seems worthy of comment. This is the finding that subjects continued to scale their grip force to apparent (rather than actual) object size, despite veridical sensory feedback on object weight. Initially, this seems surprising, as it is known that lifting behaviour can adapt rapidly to unexpected size–weight relationships[15–17] (we do not persistently over-lift a suitcase that we have discovered to be empty). Flanagan and Belzner found that the fingertip forces of subjects who repeatedly lifted large and small objects of equal weight were initially biased by visual size[16]. However, over a very few trials, force production was adjusted to the objects' true weights as subjects switched over to a memory-based strategy. That large differences in object size can have a minimal impact on force production over a few trials may seem incongruent with Jackson and Shaw's finding that small illusory size changes exert a significant influence over many trials. However, the very subtlety of the illusory size changes might be the key to understanding this result. Mon-Williams and Murray have suggested that the shift from a size-based to a memory-based representation of object weight is accelerated by increasing the discrepancy between predicted and perceived weight[17]. If so, the relatively minor discrepancies created by Jackson and Shaw's manipulation of apparent size might have been insufficient to stimulate such a shift. Moreover, the unexpected size–weight relationships encountered by Jackson and Shaw's subjects were more complex than those studied by previous authors (the various combinations of Ponzo background and object size in Jackson and Shaw's experiment created as many as twelve apparent object sizes). In this situation, where cue conflict is low and memory load high, it could be more adaptive for the system to persist in scaling fingertip forces using a simple size-based heuristic.

Two visual streams: one action

The fact that force scaling can be governed by learned object weight implies an important role for the ventral stream in modulating fingertip forces for familiar objects. Observations of patient DF further suggest that the ventral stream is involved in force scaling for novel objects. Jackson and Shaw's conclusions go slightly further than this, however. They argue that the ventral stream's role is not limited to perceptual categorization of the target object, but that the visual size cue that contributes to the final weight estimate is itself processed within the ventral stream, and is independent of size processing in the dorsal pathway. This inference depends upon the dissociated effects of the Ponzo illusion on grip force and grip aperture. Further experimentation will reveal whether this dissociation can be upheld, but Jackson and Shaw's paper nonetheless represents a valuable step forward in a field dominated by perception–action dichotomies. Their work reminds us that many aspects of visuomotor control are modulated by 'top-down' influences that embody knowledge about the world. This timely reminder might help focus attention on the important issue of how the two visual streams normally cooperate to produce behaviour that is not only spatially accurate, but also strategically appropriate.

Acknowledgements

The preliminary data reported were collected at the University of St Andrews with Chris Dijkerman, David Milner and Mark Mon-Williams. Many thanks to the above, and to Sheila McIntosh, for valuable discussion of these issues.

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Cognitive neuroscience for the 21st century

2000 Autumn School in Cognitive Neuroscience, 26–29 September 2000, University of Oxford, UK.

As we begin the new millennium it would seem to be a good idea to take stock of where the ever changing field of cognitive neuroscience stands. The annual Autumn School in Cognitive Neuroscience held at Oxford University allowed us the opportunity to do just that and to ponder on what directions the science might take in the next few years. The school (sponsored by the McDonnell-Pew and MRC Centres for Cognitive Neuroscience, University of Oxford, as well as the Guarantors of *Brain*), consists of four days of presentations, each day being thematically grouped. The themes for this year were perception, transcranial magnetic stimulation (TMS), language and, the perennial favourite, functional magnetic resonance imaging. The first day, on perception, was chaired by Andrew Parker (University of Oxford, UK), and even though the level of talks was extremely high and the speakers were of an international calibre, many delegates unfortunately considered the lavish conference banquet to be the start of the conference, arriving at Oxford only later that evening. The banquet speech was given by Martyn Davies (University of Oxford, UK), who eloquently detailed his own desires to see research on human consciousness redirected away from investigation of the neurophysiological foundations of phenomenal experience and more to understanding the so-called 'hard question' – that is, *why* do we experience distinct phenomenology? After the banquet, the delegates retired to the various bars of Oxford to discuss Professor Davies' interesting speech and to prepare themselves for the day of talks on TMS that would start the following morning.

Without doubt, the series of talks on TMS was the highlight of the school, chaired by Vincent Walsh and Alan Cowey (both University of Oxford, UK); this day brought together a number of TMS experts from around the world. Dr Walsh's contagious humour was an added bonus that ensured a virtually seamless transition between presentations. The range of talks was wide, from the explosive demonstrations of the power of TMS (Anthony Barker, Royal Hallamshire Hospital, Sheffield, UK), to a discussion of the possibility of combining TMS with other neuroscience techniques such as EEG and PET (Tomas Paus, McGill University, Montreal, Canada). The talks were complemented with a live demonstration, during the coffee breaks, by MAGSTIM (the company that makes TMS hardware), where delegates had the opportunity to experience first-hand the effects of magnetic stimulation.

The following day consisted of a number of lively discussions on a variety of topics surrounding language processing. One of the most exciting of these discussions was generated by Paul Bloom's (Yale University, USA) presentation. Bloom speculated that we develop our extensive knowledge of word meanings using a series of dedicated cognitive processors that are responsible for learning the conceptual, intentional and linguistic meaning of words. He used the development of 'Theory of Mind' abilities in children to illustrate the presence of these specialist cognitive processors. Other talks focused on specific learning impairment (SLI) (Dorothy Bishop, University of Oxford, UK; Heather van der Lely, Birkbeck College, London, UK) as evidence of dedicated 'processors' being involved. Bishop's talk integrated recent findings on the cognitive deficits and new approaches to studying the disorder. Van der Lely expanded on this theme to explore the heterogeneity of SLI, and described her work on one group of children who show a specific cognitive disability related to grammar (G-SLI). Van der Lely further went on to suggest that evidence from this G-SLI group is indicative of a genetically determined, specialized mechanism that is necessary for the development of knowledge of grammatical rules in normal human language. These presentations were complemented by that of

 PII: S1364-6613(00)01557-6