APPLIED COGNITIVE PSYCHOLOGY
Appl. Cognit. Psychol. **17**: 147–160 (2003)
Published online in Wiley InterScience 21 November 2002
(www.interscience.wiley.com) DOI: 10.1002/acp.858

Intuitions and Introspections about Imagery: The Role of Imagery Experience in Shaping an Investigator's Theoretical Views

DANIEL REISBERG,[1]* DAVID G. PEARSON,[2]
and STEPHEN M. KOSSLYN[3]

[1]*Reed College, USA*
[2]*University of Aberdeen, UK*
[3]*Harvard University, USA*

SUMMARY

Early in a scientific debate, before much evidence has accumulated, why are some scientists inclined toward one position and other scientists toward the opposite position? We explore this issue with a focus on scientists' views of the 'imagery debate' that unfolded in Cognitive Science during the late 1970s and early 1980s. We examine the possibility that, during the early years of this debate, researchers' views were shaped by their own conscious experiences with imagery. Consistent with this suggestion, a survey of 150 psychologists, philosophers, and neuroscientists showed that those who experienced their own visual imagery as vivid and picture-like recall being more sympathetic in 1980 to the view that, in general, images are picture-like. Similarly, those who have vivid images and who regularly use their images in cognition were more inclined to believe that issues of image vividness deserve more research. Copyright © 2002 John Wiley & Sons, Ltd.

It is the nature of science that theoretical disputes are usually resolved through the collection of data—data that favour one theoretical position over another, or perhaps data that demand a recasting of the scientific questions at issue. To be sure, other factors beyond the data do play a role (Barber, 1961; Brewer and Chin, 1994; Kuhn, 1963), but there is no question that the collection and scrutiny of evidence is central to the scientific process.

What should scientists do, though, prior to the evidence becoming available—e.g. while the data are accumulating? It is clear to anyone who has watched a scientific debate unfold that the participants do not remain neutral, endorsing none of the (not yet clearly supported) theoretical positions. Instead, they take a position and are then guided in their thinking by the assumptions and implications of that position. But what is it—prior to the data's becoming available—that leads a scientist to endorse one side of a theoretical dispute rather than another? And for those colleagues who do manage initially to remain neutral in a theoretical dispute, why is it that some will subsequently take a position after only a few relevant findings are available, whereas others require more and stronger evidence before taking a stance?

*Correspondence to: Daniel Reisberg, Psychology Department, Reed College, Portland OR 97202, USA.
E-mail: reisberg@reed.edu

It seems certain that many factors are pertinent to answering such questions, but probably relevant are each scientist's *intuitions*, that is, his or her pre-theoretical suppositions about what the 'correct' account is likely to be, or at least what the 'correct' account is likely to include. But, of course, this simply invites another question: Where do these intuitions come from? Again, many factors play a role, and the particular factors are likely to depend on the content of the intuition, and, with that, the content of the scientific issue at stake.

In this article, we focus on investigators working in cognitive science, and on a particular debate—namely, a debate that unfolded during the late 1970s and early 1980s concerning the internal representations that underlie mental imagery. In this debate, one group argued that visual mental imagery relies on representations that are similar in kind to those involved in other mental contents, and that all these representations are language-like propositions (e.g. Pylyshyn, 1981). Another group argued that visual imagery relies on representations fundamentally different from those involved in non-imagistic thinking, and that imagery is instantiated in a specialized analogue 'imagery medium' (e.g. Kosslyn, 1981). According to this view, visual mental imagery relies on representations that *depict*, which are distinct from representations that *describe*.

In the research described here, we explore the possibility that investigators' positions early in this debate were shaped by their *introspections*, and, in particular, by their own subjective experiences of mental imagery. Of course, cognitive scientists are taught (probably from the start of their undergraduate training) to be wary of introspections, and introspections about mental imagery in particular are often highlighted as an illustration of the difficulties inherent in introspective evidence. Nonetheless, we examine the possibility that researchers' views of mental imagery, during the early 1980s, were shaped by their experiences with imagery. Specifically, we ask whether researchers were more inclined toward the view that images are, in important ways, 'picture-like' *if* their own imagery seemed to them picture-like. Similarly, we ask whether researchers were more inclined toward believing that images have a special status in cognition if images have a special and prominent role in their own experience.

Before turning to the study, however, it may be useful to acknowledge three points of background that set the context for our data collection. First, our study takes its place within a broader range of investigations that have applied the lessons of cognitive psychology to the intellectual activities of working scientists. Thus, to name just a few examples, Vicente and Brewer (1993) asked how accurately scientists remembered the literature of their field; Mahoney and DeMonbreun (1978) examined how scientists test simple beliefs; Dunbar (1995) asked how scientists reason about actual data patterns, and so on.

These applications of cognitive psychology to the activities of scientists should not be surprising. After all, in their professional lives scientists must rely heavily on their capacities for problem solving, reasoning and memory—all capacities of central interest in cognitive psychology. It is highly plausible, therefore, that the lessons of the cognitive laboratory will be helpful in understanding how scientists proceed in their work. (For a broader context, examining the nascent 'psychology of science,' see Feist and Gorman, 1998; Tweney *et al.*, 1981.)

Second, and more closely related to the present study, a number of scholars have examined the role of *mental imagery* in scientific reasoning and problem solving. They have documented, for example, that imagery has played a an important role in shaping physicists' views across the last century; Einstein in particular was famous for his

imagined thought experiments (e.g. Miller, 1986; Shepard, 1988). Imagery is also alleged to have played a central role in the generation of many new ideas and inventions, including Kekule's discovery of the benzene ring (although, for some cautions about this often-quoted example, see Woitz and Rudofsky, 1984; for other—less controversial—examples, see Shepard and Cooper, 1982).

Third, the history of psychology also contains hints that individual differences in imagery self-reports are related to theoretical positions. For example, in his 1913 behaviourist manifesto, John B. Watson suggests that his own mental imagery used to be vivid, but is no longer: 'Until a few years ago, I thought that centrally aroused visual sensations were as clear as those peripherally aroused. I had never accredited myself with any other kind. However, closer examination leads me to deny in my own case the presence of imagery in the Galtonian sense' (Watson, 1913, p. 173, footnote 2). What brought about this change? Watson suggests that it was caused by his new clarity of vision, engendered by his behaviouristic perspective. At last, his thoughts were no longer 'warped by the fifty-odd years which [the field] had devoted to the study of states of consciousness' (p. 174), and he came to the view that mental images 'rarely come to consciousness in any person who has not groped for imagery in the psychological laboratory. This easily explains why so many of the well-educated laity know nothing of imagery' (p. 174, continuation of footnote 2).

In contrast, E. B. Titchener is perhaps the scholar whose name is most closely associated with introspection, and, according to all reports, had fabulously clear images. Indeed, he 'never used notes to give his lectures. Titchener maintained that he kept the lecture script in his mind's eye as he talked. He occasionally faltered at places where his notes had been corrected and had to shift mentally to the next line to find the inserted material' (Sommer, 1978, pp. 44–45; for Titchener's own description of these points, see, for example, Titchener, 1909, p. 8).

What should we make of these reports? As one obvious problem, we have no way to ascertain the direction of causality. Watson's own remarks imply that theoretical stance guides imagery reports, and that when one's stance changes, so do the reports. Sommer, however, suggests that cause and effect may be the other way around: 'It is perfectly understandable that a superimager such as Titchener would develop a psychological theory (introspectionism) based upon subjective reports and that a nonimager like John B. Watson would develop behaviouristic psychology, which excludes subjective experience' (p. 45).[1]

In addition to this causal ambiguity, these historical cases are also difficult to interpret for another reason. Our assessment of Titchener's or Watson's imagery necessarily relies on their self-reports, but what are we to make of such data? We have known since Galton (1883) that research participants differ enormously in how they describe their mental images, with some describing images of photographic clarity, rich in detail, almost as if they were *seeing* the imaged scene, whereas others report very sketchy images, or no images at all. Self-reports from this latter group rarely include mention of color or size or viewing perspective; indeed, their reports are largely devoid of visual qualities. In recounting Galton's data, William James (1890, p. 57) commented: 'some people undoubtedly have no visual images at all worthy of the name.'

At issue, though, is how (or whether) we can interpret these self-reports. Indeed, despite these (apparently) large differences among people, the empirical validation of vividness

[1]We are grateful to Bill Brewer and Dick Neisser for bringing these historical points to our attention.

measures has met with only mixed success. There are positive results, linking (for example) Marks' (1977) Vividness of Visual Imagery Questionnaire to performance with 'imagery tasks', but these results are sometimes difficult to understand and sometimes difficult to replicate. In addition, *negative* results, showing no relationship between imagery self-report and performance with imagery tasks, are relatively common. As a result, roughly a century after Galton's original publication, many cognitive scientists remain deeply sceptical about the value of these self-reports. (For some glimpses of this scepticism, see, for example, Katz (1983, p. 42), Kosslyn *et al.* (1985, p. 196), or Kerr and Neisser (1983, p. 213).)

We will return to all these points later in the article. For now, we note only that investigators certainly have continued to pursue the issue of imagery vividness—both on its own terms and also as part of the recent flourishing of research on conscious experience. Moreover, it seemed to us plausible that measures of imagery experience *would* be predictive in the case we were investigating, namely, the shaping of scientists' theoretic positions, at least early in the process of data-gathering and theory development. This suggestion derives from the idea that, when the relevant evidence is sparse, investigators' positions are likely to be shaped by their pre-theoretic intuitions, and that these intuitions (at least in the domain of imagery) might well be shaped by their own subjective experience.

To explore these questions, we conducted an (e-mail) survey of individuals who are now, or who have been, engaged in imagery research. All participants were asked three categories of questions. First, they were asked two questions designed to assess the nature of their own (subjectively defined) imagery and imagery use; one of these was a portion of Marks' (1977) Vividness of Visual Imagery Questionnaire, and the other was a newly designed questionnaire (Kosslyn *et al.*, unpublished). Second, they were asked a variety of questions about their views of mental imagery, including their views during the years of the 'imagery debate' and also their current views. There was also a question about the respondent's assessment of research on the topic of 'imagery vividness', and another about the respondent's views of how often, in day-to-day life, people rely on imagery. Third, and finally, we collected background information, including the participant's age and year of PhD, and also the degree to which the participant considered himself/herself well informed about the issues surrounding research on mental imagery.

METHOD

Participants

The participant list was drawn from many sources. We included psychologists, philosophers, and neuroscientists who had, in our view, published important, influential, or at least widely cited papers on the topic of mental imagery. We included all authors in several prominent edited volumes surveying research on imagery. We also included the entire list of editors from the *Journal of Mental Imagery*, and also all the academics and graduate students registered on the (electronic) mailing list for the European Workshop on Imagery and Cognition (EWIC). In constructing the participant list, we sought to include names that would span a range of ages, theoretical positions, and nationalities. Our inclusion of the entire EWIC list also ensured that our participants ranged in their level of expertise; that list includes scholars who have spent their entire professional lives investigating

imagery as well as scholars who are relatively new to the topic. In the end, our list of potential participants consisted of 356 names, and an initial e-mail was sent to all on this list, requesting their participation in the study. If we received a negative response to this e-mail, the participant was not pursued further. If we received no response, a 'reminder note' was sent. If we received either a negative response or no response to the reminder, the participant was, again, not pursued further.

Based on these initial contacts, a total of 188 surveys were sent out (again, via e-mail). One hundred and fifty of these were returned, some by e-mail and some by regular post, and so the return rate, overall, was 42% of those contacted originally, and 80% of those who agreed to participate. The resulting participant pool was (on average) roughly 40 years old, with three participants in their 70s, 14 in their 60s, and 38 in their 50s. (Bear in mind that the heyday of the 'image debate' was 20 years prior to this study, and so we needed a number of more-senior participants to ensure we had participants who were fully engaged in that debate two decades ago.) One hundred and fifteen (77%) of our participants had received a PhD, with the date of the doctorate (on average) 1980. The pool included a number of very prominent researchers in imagery, perception and memory.

Materials and procedure

The initial invitation to participate, sent in the summer of 2000, described the study as an exploration of the 'interplay between scientists' subjective experience of visual mental imagery . . . and their theoretical intuitions about this form of imagery'. For those colleagues who responded positively, the survey was sent to them, and consisted of the following items.

Question 1 contained twelve individual items that together comprise the Spontaneous Use of Imagery Scale (SUIS; Kosslyn *et al.*, unpublished). Participants were asked to read each of these items and to 'indicate the degree to which each is appropriate for them', using a 1–5 scale (with a 5 indicating 'completely appropriate', and a 1, 'never appropriate'). The items were from a newly constructed scale designed to measure (self-reported) spontaneous use of imagery. Sample items include 'If I am looking for new furniture in a store, I always visualize what the furniture would look like in particular places in my home' and 'When I first hear a friend's voice, a visual image of him or her almost always springs to mind'.

Question 2 contained four of the 16 questions that constitute Marks' (1977) Vividness of Visual Imagery Questionnaire (VVIQ). We used only this excerpt from the VVIQ simply in the interests of brevity. We knew the respondents to this survey were busy colleagues, and we wished to make the survey as brief as possible. Analyses of the split-half reliability of the VVIQ have found its internal consistency to be within acceptable limits (Marks, 1973, 1987; McKelvie, 1986; McKelvie and Gingras, 1974), and the evidence also indicates that VVIQ items all load onto a single factor (Childers *et al.*, 1985; McKelvie, 1995; Richardson, 1999). On this basis, we felt that using a subset of the VVIQ questions could provide us with a reliable estimate of participants' image vividness. The specific questions we used began by urging participants to 'visualize a rising sun', and then to rate the 'picture' that came before their 'mind's eye' with regard to four aspects of the scene ('The sun is rising above the horizon into a hazy sky', and so on). The response options were the standard options on the VVIQ: '1—perfectly clear and vivid as normal vision; 2—clear and reasonably vivid; 3—moderately clear and vivid; 4—vague and

dim; 5—No image, you just know you are thinking of the object.' No specific instructions were given (as they sometimes are for the VVIQ—cf. Marks, 1977) as to whether the respondents should have their eyes open or shut while making these ratings.

Question 3 was the first of our target variables. The question noted that 'for many years, investigators interested in visual imagery were engaged in a series of theoretical disputes often referred to as ''The Imagery Debate''.' If participants were not following that debate as it unfolded, they were urged to skip this question. If they had followed the debate, they were asked to choose the statement that best matched their position 'in, say, 1980 or so'. There were four response options. One option indicated that 'I was sympathetic to the idea that, in many important ways, image representations are depictive, *and* that these depictive aspects are actually used in information processing'. A second option indicated that 'I was sympathetic to the idea that, in many important ways, image representations are depictive, *but* also concerned about qualities that *distinguish* mental images and pictures'. A third option was that 'I was sympathetic to the idea that image representations are *not* depictive', or to the idea that any picture-like aspects that images do have 'play little role in information processing'. A final option was that 'I was not sure what to conclude'.

We acknowledge that these four response options do not provide an ideal way of characterizing complex, often subtly nuanced theoretical positions. Nonetheless, we hoped these options would at least allow us to characterize the respondents' views in broad strokes, and, again, we were concerned about the brevity of the questionnaire, and this dissuaded us from asking a larger number of more fine-grained questions. In addition, we should note that the entire questionnaire was administered to ten pilot subjects to check the clarity of the items and to determine how much time the participants would need to complete the survey. None of the pilot subjects expressed any confusion about the survey's questions, nor dissatisfaction with the available response alternatives.

Question 4 probed the respondent's reading of the *currently available evidence*. The response options were the same as those for Question 3.

Question 5 asked whether the respondent considered himself/herself 'very well informed about research on the topic of visual imagery', 'reasonably well informed', 'somewhat familiar' with this research, or only 'marginally keeping track of research on the topic of visual imagery'.

Question 6 began by noting that there 'has been considerable disagreement in the literature over the value of subjective self-assessments of imagery ''vividness''. The respondents were then asked their view; these were the response options: '(a) measures of imagery vividness have no empirical value, thanks to the familiar problems involved in self-report; (b) measures of imagery vividness are likely to be imprecise, because of problems in self-report, but still capture an underlying difference among individuals; (c) measures of imagery vividness have value as measures of imagery, and are likely to be predictive of performance on some imagery tasks'.

Question 7 began by noting that 'some people claim that they routinely rely on imagery in their ordinary day-to-day cognition—perhaps as an aid to problem-solving, perhaps as an aid to memory'. The question then asked what percentage of adults the respondent believed routinely relied on imagery in this fashion.

Finally, *Questions 8* and *9* asked in what year the respondent had received his or her PhD, and how old the respondent was (to the nearest decade). *Question 10* asked the nature of the respondent's current post (full-time faculty, full-time research, post-doc, research staff, etc.), and *Question 11* asked the respondent's area of specialization (cognitive psychology, cognitive neuroscience, philosophy, etc.).

Table 1. Summary of all measures

Question	Mean	*SD*	*n*
1. SUIS	3.11	0.66	150
2. VVIQ	2.60	1.01	150
7. What % rely . . . ?	60.5	24.27	140
8. Year of PhD	1980	11	115
9. Age	39.4	13.1	149
	Frequency distribution for the various response options		
	1	2	3	4
3. Position in 1980	31	46	7	6
4. Current position	41	84	9	9
5. How well informed?	41	65	31	12
6. Value of vividness measures	11	100	32	—

Notes:
(1) In most cases, values of *n* below 150 indicate that some participants simply skipped the relevant question. For 'year of PhD', however, a number of participants indicated either that they had never sought a PhD or that they had not yet received this degree. The *n* is also lower for the 'position in 1980' question because participants were specifically urged to skip this question if they were not following the imagery debate as it unfolded.
(2) Four response options were available for questions 3,4 and 5; only three options were offered for question 6. (See text for details.)

RESULTS

Descriptive data

Table 1 provides a descriptive summary of our results. As can be seen, our respondents differed broadly in their imagery self-reports. On the VVIQ, responses ranged across the entire response scale, from a minimum of 1 to a maximum of 5, with a mean of 2.6. (Bear in mind that the standard scoring scheme for this test uses *low* numbers to indicate vivid imagery, and higher numbers to indicate sparse imagery; a response of 5 indicates 'no image at all'.) On the Spontaneous Use of Imagery Scale (SUIS), the average response was 3.1 (the middle of the five-point response scale), but answers ranged over virtually the entire scale (minimum score = 1.2, maximum = 4.7).

Ninety of our participants indicated what their theoretical position was in 1980 (i.e. during the imagery debate), and, as the table shows, they had a range of different views. Four more participants indicated that they were not satisfied with our response alternatives, and all four chose to check off both our first and second response options. These participants were excluded from the analyses below.

One hundred and forty-three participants indicated what their views were of the *currently available evidence*, and again expressed a range of different perspectives, although the modal position (endorsed by 59% of the respondents) was that 'image representations are depictive', and that there are also qualities 'that distinguish mental images and pictures'. Three other participants elected to skip this question; four others chose to check off multiple response options. Again, these participants were excluded from the analyses below.

VVIQ and 'position in 1980'

Of the participants who answered the question about their (recollection of) their position during the years of the imagery debate, roughly one-third indicated that their position then was consistent with the most 'pro-pictorial' sentiment we offered; only seven indicated a position consistent with the opposite extreme (i.e. the claim that images are either 'not depictive' or 'play little role'). According to an analysis of variance, there was a reliable relationship between these responses and respondents' VVIQ scores, $F(3, 86) = 3.59$, $p < 0.02$. *Post-hoc* testing shows that those who recalled endorsing the 'pro-pictorial' position had reliably lower VVIQ scores (mean = 2.14, $SD = 0.83$, $n = 31$), and hence more vivid imagery, by self-report, than those who recalled endorsing the sentiment that included a concern about 'qualities that *distinguish* mental images and pictures' (mean = 2.88, $SD = 1.00$, $n = 46$; for the contrast, $p = 0.002$ by a Fisher's PLSD test). Similarly, *post-hoc* testing showed that those who recalled endorsing the 'pro-pictorial' position had lower VVIQ scores (indicating more vivid imagery) than those who believed then that 'images are *not* depictive' (for the latter group, mean = 2.89, $SD = 1.58$, $n = 7$), although this contrast narrowly missed standard significance levels ($p < 0.08$ by a PLSD test). No other *post-hoc* comparisons neared statistical reliability. Appropriately, those who indicated that they were 'not sure what to conclude' during the imagery debate had VVIQ scores midway between those endorsing the pictorial view and those opposing it (mean VVIQ for the 'not sure' respondents = 2.67, $SD = 0.89$, $n = 6$).

As another way of documenting this pattern, we can reverse the logic of the analysis and treat VVIQ as the categorical variable and 'position in 1980' as the dependent measure. Table 2 shows the resulting frequency distributions. Among the participants with relatively vivid imagery (VVIQ scores of 2 or lower), 60% (15 of 25) endorsed the 'pro-pictorial' sentiment that images are depictive and play a role in information processing. Among the thirteen participants with relatively sparse imagery (VVIQ of 4 or higher), *zero* participants endorsed this sentiment. The contrast between these two distributions of responses is reliable; $\chi^2 = 13.56$, df = 3, $p < 0.01$. The same pattern is visible if we consider only the most extreme VVIQ scores: For those participants with a VVIQ score of 1.0, half (four of eight) endorsed the 'pro-pictorial' sentiment. For those with a VVIQ score of 5.0, none (out of four) endorsed this sentiment.

VVIQ and 'position now'

One hundred and forty-three participants answered the question about their current views of imagery. There was no relationship between these responses and VVIQ: $F(3, 139) < 1$, $p > 0.60$. (The mean VVIQ scores, with the data partitioned by response to the 'position now' question, were 2.42, 2.66, 2.61, 2.63, with standard deviations in each case of 0.9 or higher. There was, in other words, no hint of a difference among these scores.) Similarly,

Table 2. Frequency distribution for responses to 'position in 1980' question, partitioned by VVIQ score

	VVIQ	Response to 'position in 1980'			
		1	2	3	4
'High vividness' imagers ($n = 25$)	≤ 2.0	15	6	3	1
'Low vividness' imagers ($n = 13$)	≥ 4.0	0	10	2	1

there is no reliable pattern if we categorize participants according to their VVIQ scores, and (in the fashion of Table 2) examine the resulting distributions of responses to the 'position now' question.

We note that, in our view, it is entirely sensible that the 'position now' responses are unrelated to imagery vividness (measured via the VVIQ). This is because a large quantity of data has by now accumulated concerning the nature of mental imagery, and so intuitions should play a smaller role in one's choice of a theoretical position now than they did twenty years ago. However, another interpretation is also possible for this contrast between 'position now' and 'position in 1980.' Our data concerning 'position now' include a number of younger colleagues, colleagues who were in no way involved in the imagery debate two decades back. Perhaps it is this difference in cohort, therefore, that accounts for the data pattern. To evaluate this possibility, we also examined the relationship between 'position now' and VVIQ for only those participants who had received their PhD in 1985 or earlier (and so people who were in graduate school or beyond during the years of the imagery debate). In this subset of the data (sixty cases), there is still no relationship between current position and VVIQ, $F(3, 62) < 1$, $p > 0.70$, nor is there a reliable contrast between low- and high-vividness imagers if we categorize this subset of the data in the fashion of Table 2.

VVIQ and 'value of vividness research'

If we view our 'value of vividness' question as offering a ordered scale of responses, then the appropriate analysis is a correlation between participants' VVIQ scores and their responses to the 'value' question. The correlation value is -0.25 ($\mathrm{df} = 135$, $p < 0.02$). The negative sign indicates an association between higher vividness (lower VVIQ score) and greater perceived value for research on vividness. Said differently, it tends to be those with the most vivid imagery who feel that measures of image vividness have value (e.g. as performance predictors).

It is interesting to note, however, that this correlation arises primarily from those participants who do not consider themselves well informed about imagery research. If we consider only those participants who consider themselves merely 'somewhat familiar' with research on visual imagery or only 'marginally keeping track' of this research ($n = 43$), then the correlation value is -0.31. If we consider only those participants who consider themselves 'very well' or 'reasonably well informed' ($n = 106$), the correlation is -0.16. This is, of course, consistent with the hypothesis we are exploring: The more one knows about the relevant data, the less room in one's judgement for intuitions, and so the smaller the role for factors that might shape those intuitions.

VVIQ and 'what percentage relies on imagery'

Again, a correlational measure seems appropriate for this comparison, and, in fact, there is no reliable correlation between these two measures, $r = -0.06$ ($\mathrm{df} = 148$, ns).

Internal consistency of the SUIS

This is a newly devised measure and so it first seemed appropriate to check on the internal consistency of the measure. For that purpose, correlations were computed for each of the twelve items on this measure and the measure's total *minus* that item. All twelve of these

correlations were 0.98 or higher, indicating an extremely high degree of internal consistency (and also indicating that this measure could be shortened appreciably without loss of information).

SUIS and our other measures

Few reliable relationships were observed between the spontaneous-use measure and our other measures. There was no reliable relation between the SUIS and our participants' recall of their 1980 stance on imagery, or their current stance on imagery. In the full data set, there was no reliable correlation between the SUIS and participants' assessment of the value of vividness research, or their estimates of the percentage of people who rely on imagery. Once again, though, a trend emerged if we look only at those participants who considered themselves only 'somewhat familiar' or 'marginally familiar' with imagery research. In this subset of the data, participants who described themselves as very likely to use imagery spontaneously (high scores on the SUIS) tended to be those who place a higher value on measures of imagery vividness ($r = 0.26$, $\mathrm{df} = 41$, $p < 0.10$).

In addition, we found a relationship between the SUIS and VVIQ. If we again categorize participants into 'high-vividness' imagers (VVIQ of 2 or lower) and 'low-vividness' imagers (4 or higher), we find a small but reliable difference between these two groups in their spontaneous-use scores, $F(1, 74) = 4.84$, $p < 0.04$. Not surprisingly, the high-vividness imagers ($n = 54$) have a somewhat higher score on the SUIS, with a mean of 3.27 ($SD = 0.68$), in contrast to a mean of 2.88 ($SD = 0.77$) for the low-vividness imagers ($n = 22$).

DISCUSSION

Taken at face value, our data lend themselves to a simple account. In the absence of firm data on an issue, investigators are heavily influenced in their thinking by their own pre-theoretic intuitions. Those intuitions, in turn, can sometimes be guided by one's conscious experience: Those who experience their own visual imagery as picture-like will be more sympathetic to the view that, in general, images are picture-like (or, more precisely, to the view that images are depictive, and that the depictive aspects have functional importance). Investigators who have vivid images and who regularly use images in memory and cognition are more inclined to believe that measures of image vividness have value and can serve as performance predictors.

But is it appropriate to take the current data at face value? After all, the data are correlational, which rules out any strong claims about *causal* connections. In addition, some of our data (e.g. the 'position in 1980' question) rely on participants' memory for what they thought twenty years ago; can the veracity of this memory be taken for granted? Finally, the imagery self-report measures themselves are necessarily introspective, and the VVIQ in particular relies on a response scale that is not objectively anchored, which clouds interpretation of the data still further. (It is certainly possible, for example, that different participants intend very different things by the phrase 'perfectly clear and vivid as normal vision'.)

We do not wish to trivialize these concerns, and, indeed, we placed these concerns in plain view in introducing the present study. Clearly, therefore, we must be cautious in interpreting the data. Nonetheless, we believe these concerns do not fatally compromise

our findings. The difficulties inherent in introspection, for example, seem likely to add noise to the data, weakening any underlying patterns. As we have seen, though, the data do show reliable patterns, suggesting the level of noise cannot have been too damaging. Moreover, there is no way to escape a reliance on introspection, given the nature of the hypothesis we are pursuing!

The reliance on memory seems less troublesome in this arena than it might be in a more conventional study of autobiographical recall. We certainly know that people can misremember their own past—can misremember their previous health status, their previous financial circumstances, and so on (Ross and Wilson, 2000; Ross and Newby-Clark, 1998). But these cases seem different from the point at issue here—namely, the prospect of misremembering one's own professional views. The memories needed for our questionnaire (e.g. the 'position in 1980' question) are, after all, likely to be well rehearsed, the product of numerous conversations about these issues during the 1970s and 1980s, and are also, for many of our participants, rooted in their professional publications from that era. These should be powerful memory aids, substantially diminishing the risk of memory error. In addition, we asked our participants to characterize their past positions only in broad outline. Therefore, some amount of memory inaccuracy, even if it occurred, would probably leave our data patterns largely intact, again diminishing the force of this concern.

What about the fact that our data are correlational? It is possible, for example, that imagery-experience does not guide pre-theoretical intuitions, but instead intuitions guide how people describe their imagery experience. Or another variable might be influencing both imagery self-report *and* scientific intuitions; for example, one might argue that some participants are cautious and others not, and conceivably it is the cautious participants who are modest in their descriptions of their imagery (high-VVIQ) and who were slow to endorse the 'pictorial' view of imagery in 1980.

Hypotheses like these might seem plausible individually, but our data set provides more than a single correlation to be explained, and none of the hypotheses just sketched seems promising as an account of the full pattern of data. For example, if high VVIQ scores are merely serving as an index of 'caution', then it is puzzling that we observed no correlation between VVIQ and the 'per cent relies' measure; this measure, too, one would think, would be influenced by the respondent's caution. Similarly, if theoretic intuitions guide how people describe their imagery experience, then why is there no relationship between *current* position and VVIQ? (This point, incidentally, also rules out a simple 'hindsight bias' account of our findings.) Questions like these seem to require *ad hoc* modifications of the hypotheses just sketched (and many others like them), and this leads us to set aside these alternative accounts of the data. Rather, imagery experience does seem to influence pre-theoretic intuitions, but this influence wanes as more empirical evidence becomes available.

Similar arguments apply to another concern often voiced about the VVIQ, namely, that the scale is largely an index of an individual's sensitivity to issues of 'social desirability' (cf. DiVesta *et al.*, 1971; see also Richardson, 1980; McKelvie, 1995). The logic of this concern is that most people perceive vivid imagery to be a desirable capacity, and so people particularly sensitive to this social issue might be prone to overstate the vividness of their images. Once, again, though, it is not clear how to extend this idea (or other, related, concerns) to explain our data pattern. It is certainly not obvious, for example, why on this account VVIQ scores were predictive of past position, but not current position.

Our confidence in interpreting our findings at face value is bolstered further by recent evidence suggesting that—despite its chequered history—the VVIQ is a valid

(albeit noisy) measure of imagery experience. In a quantitative review of the published literature on the VVIQ, McKelvie (1995) has argued that the evidence is generally favourable to the construct validity of the VVIQ as a psychometric test of individual differences in visual imagery vividness. Many studies have also increasingly used image vividness as a factor that can be manipulated via selective interference with other cognitive systems, which further demonstrates its validity as a dependent variable. Andrade *et al.* (1997) have reported reductions in image vividness by concurrent eye or hand movements, while Baddeley and Andrade (2000) have found that ratings of image vividness show an interaction between image modality (visual or auditory) and the modality of a concurrent secondary task. These studies suggest that there is a strong link between the phenomenological vividness of images and corresponding activation within working memory.

But what exactly does it *mean* to be a 'vivid imager'? Here we can only offer speculation, based on the available evidence. As a start, we should acknowledge that many different factors are likely to influence vividness judgements, including the degree of elaboration of the image, the degree of resolution, the refresh rate, how one pays attention to the image, and so on. (For more on the many factors that might influence vividness judgements, see Pearson *et al.*, 2000; Baddeley and Andrade, 1998; Cornoldi *et al.*, 1992. For more on the difficulties involved in *measuring* vividness, see McKelvie, 1995; Reisberg and Heuer, 1988.) However, it seems likely that vividness judgements in general are shaped to a large extent by the degree of *subjective resemblance* between images and visual percepts. (Indeed, this degree of resemblance is arguably at the heart of what the VVIQ measures, with a response scale that is anchored by an option that explicitly compares imagery to vision.)

What is it that determines this degree of resemblance? It may be helpful here to note that many authors have suggested a distinction between 'visual' images and 'spatial' images. Visual (or 'depictive') images represent exactly what a shape looks like, including its surface textures and colours, are disrupted by simultaneous visual tasks, and are probably realized in the visual cortex. Spatial images represent an object's shape and layout, but not its textures or colours, are disrupted by simultaneous motor tasks, and are probably realized in large part in the parietal and motor cortex. (For two different views of this distinction, and a review of the relevant evidence, see Kosslyn and Thompson, 2000; Reisberg and Heuer, 2002.) With this distinction in mind, one obvious hypothesis would be that someone with vivid imagery would have representations that are more 'visual' than 'spatial' in nature, and, in addition, would have representations that rely heavily on many of the mechanisms ordinarily used for visual perception. This leads to the suggestion that the degree of subjective vividness will have a number of neural correlates that reflect an association between vividness and, for example, activity levels in the visual cortex, and there is at least some indication in the literature that this is correct—i.e. a correlation between vividness by self-report and levels of activation in the occipital lobe (e.g. Farah and Peronnet, 1989; Goldenberg *et al.*, 1990). Clearly, though, this is an issue to be explored further.

These conjectures to the side, the present results join the growing body of evidence that ties vividness self-reports to other empirical measures. This in turn adds to the suggestion that these self-reports can be taken seriously, and, indeed, adds to the argument, offered by Galton more than a century ago, that humans differ substantially in their subjective experiences and that these differences have functional consequences. Moreover, the present data provide at least one glimpse of how subjective experience can shape a scientific investigator's pre-theoretical views. We can only speculate about whether

similar patterns will emerge in other areas of research (including dream research, consciousness studies, the examination of decision making, and so on), and this too is plainly an issue that needs to be explored further.

ACKNOWLEDGEMENTS

We wish to thank Cara Laney for her enormous help in collecting and analyzing the data. We also wish to thank the 150 colleagues who generously gave us their time for this study.

REFERENCES

Andrade J, Kavanagh D, Baddeley AD. 1997. Eye-movements and visual imagery: a working memory approach to the treatment of post-traumatic stress disorder. *British Journal of Clinical Psychology* **36**: 209–223.

Baddeley AD, Andrade J. 1998. Working memory and consciousness: an empirical approach. In *Theories of Memory* (Vol. II), Conway MA, Gathercole SE, Cornoldi C (eds). The Psychology Press: Hove.

Baddeley AD, Andrade J. 2000. Working memory and the vividness of imagery. *Journal of Experimental Psychology: General* **129**: 129–145.

Barber B. 1961. Resistance by scientists to scientific discovery. *Science* **134**: 596–602.

Brewer WF, Chin CA. 1994. *Scientists' Responses to Anomalous Data: Evidence from Psychology, History, and Philosophy of Science* (Vol. 1). MI; Philosophy of Science Association: East Lansing, 304–313.

Childers TL, Houston MJ, Heckler SE. 1985. Measurement of individual differences in visual versus verbal information processing. *Journal of Consumer Research* **12**: 125–134.

Cornoldi C, De Beni R, Cavedon A, Mazzoni G, Giusbert F, Marcucci F. 1992. How can a vivid image be described? Characteristics influencing vividness judgements and the relationship between vividness and memory. *Journal of Mental Imagery* **16**: 89–108.

DiVesta F, Ingersoll G, Sunshine P. 1971. A factor analysis of imagery tests. *Journal of Verbal Learning and Verbal Behavior* **10**: 471–479.

Dunbar K. 1995. How scientists really reason: scientific reasoning in real-world laboratories. In *The Nature of Insight*, Sternberg RJ, Davidson JE (eds). MIT Press: Cambridge, MA; 365–395.

Farah MJ, Peronnet F. 1989. Event-related potentials in the study of mental imagery. *Journal of Psychophysiology* **3**: 99–109.

Feist GJ, Gorman ME. 1998. The psychology of science: review and integration of a nascent discipline. *Review of General Psychology* **2**: 3–47.

Galton F. 1883. *Inquiries into Human Faculty.* Dent: London.

Goldenberg G, Podreka I, Steiner M. 1990. The cerebral localization of visual imagery: evidence from emission computerized tomography of cerebral blood flow. In *Imagery: Current Developments. International Library of Psychology*, Hampson PJ, Marks DF (eds). Routledge: London, England UK; 307–332.

James W. 1890. *The Principles of Psychology* (Vol. II). Dover Publications: New York.

Katz A. 1983. What does it mean to be a high imager? In *Imagery, Memory and Cognition*, Yuille J (ed.). Erlbaum: Hillsdale, NJ.

Kerr NH, Neisser U. 1983. Mental images of concealed objects: new evidence. *Journal of Experimental Psychology: Learning, Memory and Cognition* **9**: 212–221.

Kosslyn SM. 1981. The medium and the message in mental imagery: a theory. *Psychological Review* **88**: 46–66.

Kosslyn SM, Brunn J, Cave K, Wallach R. 1985. Individual differences in mental imagery ability: a computational analysis. *Cognition* **18**: 195–243.

Kosslyn SM, Thompson WL. 2000. Shared mechanisms in visual imagery and visual perception: insights from cognitive neuroscience. In *The New Cognitive Neurosciences*, Gazzaniga MS (ed.). MIT Press: Cambridge, MA.
Kuhn TS. 1963. The function of dogma in scientific research. In *Scientific Change: Historical Studies in the Intellectual, Social and Technical Conditions for Scientific Discovery and Technical Invention, from Antiquity to the Present*, Crombie AC (ed.). Heineman: London; 347–369.
Mahoney M, DeMonbreun B. 1978. Problem-solving bias in scientists. *Cognitive Therapy and Research* **1**: 229–238.
Marks DF. 1973. Visual imagery differences in the recall of pictures. *British Journal of Psychology* **64**: 17–24.
Marks DF. 1977. Imagery and consciousness: a theoretical review from an individual differences perspective. *Journal of Mental Imagery* **12**: 275–290.
Marks DF. 1987. Resolving the unvividness paradox. *Journal of Mental Imagery* **11**: 3–9.
McKelvie SJ. 1986. Effects of format of the Vividness of Visual Imagery Questionnaire on content validity, split-half reliability, and the role of memory in test–retest reliability. *British Journal of Psychology* **77**: 229–236.
McKelvie SJ. 1995. The VVIQ as a psychometric test of individual differences in visual imagery vividness: a critical quantitative review and plea for direction. *Journal of Mental Imagery* **19**: 1–106.
McKelvie SJ, Gingras PP. 1974. Reliability of two measures of visual imagery. *Perceptual and Motor Skills* **79**: 417–418.
Miller A. 1986. *Imagery in Scientific Thought*. MIT Press: Cambridge, MA.
Pearson DG, De Beni R, Cornoldi C. 2000. The generation, maintenance, and transformation of visuo-spatial mental images. In *Imagery, Language and Visuo-Spatial Thinking*, Denis M, Logie RH, Cornoldi C, de Vega M, Engelkamp J (eds). The Psychology Press: Hove; 1–27.
Pylyshyn Z. 1981. The imagery debate: analogue media versus tacit knowledge. *Psychological Review* **88**: 16–45.
Reisberg D, Heuer F. 1988. Vividness, vagueness, and the quantification of visualizing. *Journal of Mental Imagery* **12**: 89–102.
Reisberg D, Heuer F. 2002. Visuospatial imagery. In *Handbook of Visuospatial Thinking*, Shah P, Miyake A (eds). Cambridge University Press: New York.
Richardson JTE. 1980. *Mental Imagery and Human Memory.* St Martin's Press: New York.
Richardson JTE. 1999. *Imagery.* Psychology Press: Hove.
Ross M, Newby-Clark IR. 1998. Construing the past and future. *Social Cognition* **16**: 113–150.
Ross M, Wilson A. 2000. Construing and appraising past selves. In *Memory, Brain, and Belief*, Schacter DL, Scarry E (eds). Harvard University Press: Cambridge, MA; 231–258.
Shepard RN. 1988. The imagination of the scientist. In *Imagination and Education*, Egan K, Nadaner D (eds). Teachers College Press: New York; 153–185.
Shepard RN, Cooper LA. 1982. *Mental Images and Their Transformations*. MIT Press: Cambridge, MA.
Sommer R. 1978. *The Mind's Eye: Imagery in Everyday Life*. Delacorte Press: New York.
Thompson WL, Kosslyn SM. 2000. Neural systems activated during visual mental imagery: a review and meta-analyses. In *Brain Mapping II: The Systems*, Toga AW, Mazziotta JC (eds). Academic Press: San Diego, CA.
Titchener EB. 1909. *Lectures on the Experimental Psychology of the Thought-Processes*. Macmillan: New York.
Tweney RD, Doherty ME, Mynatt CR (eds). 1981. *On Scientific Thinking*. Columbia University Press: New York.
Vicente K, Brewer W. 1993. Reconstructive remembering of the scientific literature. *Cognition* **46**: 101–128.
Watson JB. 1913. Psychology as the behaviorist views it. *Psychological Review* **20**: 158–177.
Woitz JH, Rudofsky S. 1984. Kekule's dreams: fact or fiction? *Chemistry in Britain* **20**: 720–723.

