Perception, 1977, volume 6, pages 7–14

Do monkeys' subjective clocks run faster in red light than in blue?

Nicholas K Humphrey, Graham R Keeble
Sub-Department of Animal Behaviour, University of Cambridge, Madingley, Cambridge CB3 8AA
Received 23 July 1976

Abstract. When monkeys are given control of the illumination in a testing chamber, it has been found, under three conditions, that they spend less time with red light than with blue. But the results cannot easily be explained in terms of 'preference'. Rather, the results suggest that monkeys judge 'subjective time' to pass nearly twice as fast in red light as in blue.

1 Introduction

On the basis of what he believed to be a test of 'colour preference' Humphrey has claimed that rhesus monkeys find blue light more pleasant than red and, indeed, that they have "a strong aversion to light at the red end of the spectrum" (Humphrey 1971, 1972; Humphrey and Keeble 1975). We have made new observations on the reactions of monkeys to red and blue light which, while corroborating the facts of the earlier experiments, render the interpretation in terms of 'pleasantness' improbable. At a behavioural level the most that can safely be said from this series of experiments is that monkeys 'do things faster' in red light than in blue. This phenomenon may have nothing to do with liking or disliking of the colours but may instead reflect an influence of colour on the passage of subjective time.

The technique for measuring 'preference' has been described as follows (Humphrey 1972): "The monkey sat in a dark chamber with a screen at one end onto which visual stimuli could be projected under the monkey's control. In any one experimental session the monkey had a choice of two stimuli. When he pressed a button, he got one of the stimuli for as long as he held the button down. When he let go, the stimulus went off, and the next press on the button produced the other stimulus. Another press and the first stimulus was restored, and so on in strict alternation. *To exercise a preference the monkey had simply to hold the button down when he wanted the current stimulus, and release and press again when he wanted the other*" (italics added).

But things are not in reality so simple. It is true that, if a monkey in this situation wants one stimulus (call it stimulus X) more than another stimulus (call it stimulus Y), then he may be expected to hold the button down longer for X than for Y. But it would be a fallacy to suppose that if a monkey does in fact hold on to stimulus X longer than stimulus Y then he must be doing so because he wants X more than Y. The same observed behaviour might result if, say, the monkey were simply to be more fidgety in the presence of Y than X and therefore more likely 'accidentally' to let go the button; or, as will be explained below, it might result if the monkey's sense of timing were to be changed by the stimuli so that he thought that a short interval in the presence of Y were equal to a longer interval in the presence of X. Thus the earlier report that monkeys, given the choice between blue light and red light, spend longer with the blue than with the red is open to more than one interpretation.

2 Outline of the experiments

This paper describes three related experiments.

(i) In *experiment 1* the monkeys were given a choice between red and blue light according to the 'preference' paradigm described above. In other words the chamber was dark unless the monkey pressed the button, and successive presses produced red and blue in alternation. The purpose of experiment 1 was to confirm that in this situation the monkeys would tend to hold the button down longer for blue than for red (the mean time between pressing the button and releasing it is hereafter referred to as the mean 'hold time').

(ii) In *experiment 2* the situation was essentially the same as in experiment 1 except that now the monkeys had no choice of colour. In other words the button either produced red at every press or else blue at every press, depending on whether it was a 'red' or a 'blue' test. The purpose of experiment 2 was to see whether the mean hold time for blue would still be greater than that for red even when the monkey could not change the colour by releasing the button and pressing again.

(iii) In *experiment 3* the button again produced either red at every press or blue at every press, but now instead of darkness *the alternative colour* returned to the screen whenever the monkey let go. Thus the monkeys had no need to press the button merely to illuminate the chamber but could, if they chose, sit passively with the alternative colour: in a 'press for red' test they could press for red or sit passively with blue, in a 'press for blue' test they could press for blue or sit passively with red. The purpose of experiment 3 was first to see whether under these conditions the monkeys would press the button at all (in particular whether they would press for red when sitting in blue), and second—provided they did press—to examine the quantitative relation between the mean hold times for red and blue and the mean times spent passively *between* presses.

Paradigms for the three experiments are set out in figure 1.

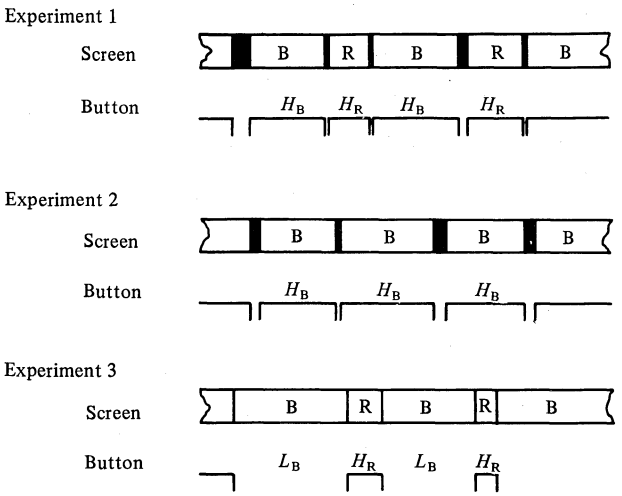

Figure 1. The three experimental paradigms. (i) Experiment 1: the monkey could alternate between red and blue, with darkness intervening between presses. (H_R, the 'hold time' for red; H_B, the 'hold time' for blue.) (ii) Experiment 2: in a 'blue test' (as shown) the monkey could press only for blue, with darkness intervening between presses; in a 'red' test he could press only for red, with darkness intervening between presses. (H_R, the 'hold time' for red; H_B, the 'hold time' for blue.) (iii) Experiment 3: in a 'press for red' test (as shown) the monkey could press for red with blue intervening between presses, in a 'press for blue' test he could press for blue with red intervening between presses. (H_R, the 'hold time' for red; H_B, the 'hold time' for blue; L_R, the 'latency' for red; L_B, the 'latency' for blue.)

3 Methods

The apparatus (figure 2) has been described in detail in an earlier paper (Humphrey 1972). The testing chamber was a rectangular metal box, black inside, with a 40 cm by 40 cm ground Perspex screen taking up one wall. The response button was a lightly sprung Grason-Stadler 'primate push button'. Stimuli were back-projected by Forth Instrument tachistoscopic slide projectors with silent shutters.

The stimuli were homogeneous fields of colour which covered the whole screen. They were produced by gelatin filters in the projectors (Kodak Wratten filters 38A and 25). Red and blue stimuli were matched in subjective brightness at 1·5 log-ft-lamberts for the human eye, which has the same spectral sensitivity as that of the rhesus monkey.

At the beginning and end of each testing session the chamber was illuminated by white houselights. Extinction of these houselights marked the start of the test. In experiments 1 and 2 each test ran from the point at which the houselights were extinguished until such time as the monkey had held down the button for a cumulative total of 400 s; this meant that, including the brief intervals spent in the dark between presses, the test generally lasted about 450 s. In experiment 3 the test lasted exactly 400 s, independently of how much the monkey pressed the button. At the end of each test the monkey was given two peanuts from an automatic dispenser.

Measurements were made of the total number of presses and the total time with each stimulus during each quarter of the test. From these it was possible to calculate mean hold times, etc, and to plot them as a function of time into the test. In the graphs below, the results for each quarter of the test have been collapsed to give the results for each half.

Tests were run twice a day, in the morning and afternoon. Each of the three experiments comprised ten consecutive tests, in a balanced design. In experiment 1, all ten tests gave the monkey a chance to press both for red and for blue; in experiment 2 five of the tests were tests where he could press only for red, and five were tests where he could press only for blue; in experiment 3 five of the tests were tests where he could press for red or sit passively with blue, and five were tests where he could press for blue or sit passively with red. Although experiment 3 is described last in this paper it was in fact done first, and was followed after a break of one month by experiment 1 and then experiment 2.

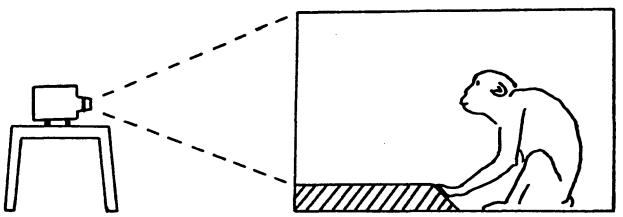

Figure 2. Diagram of the testing chamber.

4 Subjects

The subjects of the experiments were six young male rhesus monkeys (*Macaca mulatta*). Four of these took part in all three experiments, but on account of ill health one took part only in experiment 3 and another only in experiments 1 and 2. Thus there were five monkeys in each experiment. The monkeys had been pretrained to press the button in darkness to obtain white light and had been given extended practice in this simple situation. Prior to the present experiments they had not had experience of coloured light in the testing chamber.

5 Results

5.1 *Experiments 1 and 2*

Refer to figure 1 for illustration of the experimental paradigms. The important difference between experiments 1 and 2 was that in the former the monkeys had a 'choice' of colour but in the latter none. Figure 3 shows how the five monkeys behaved in these contrasting situations in terms of mean hold times in the first and second halves of the tests. In both situations the mean hold time for blue (H_B) was greater than that for red (H_R) throughout the test, and this was true for all five monkeys. Figure 4 shows the ratios of the hold time for blue to the hold time for red at corresponding points of the tests within the two experiments. The colour effect, measured by this ratio, was only slightly less in experiment 2 than it was in experiment 1.

5.2 *Experiment 3*

Refer again to figure 1 for the experimental paradigm. Since in this experiment the monkeys were not required to do anything either to illuminate the screen or to bring the test to an end after 400 s, they might well have proved to be comparatively inactive (especially in those sessions where inactivity meant that the screen remained blue).

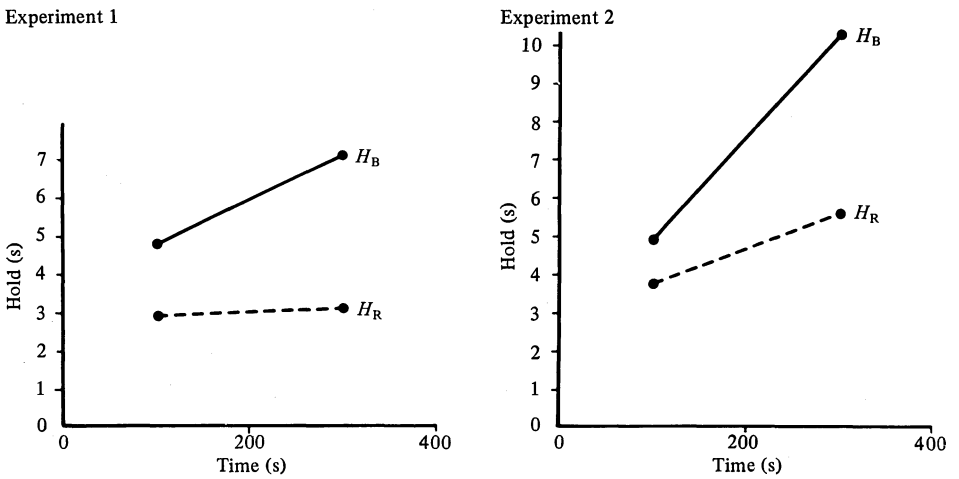

Figure 3. Mean hold times over the course of the test in experiments 1 and 2 (pooled results for all five monkeys). In experiment 1, H_B and H_R were measured within the same tests; in experiment 2, H_B was measured in the 'blue' tests, and H_R in the 'red' tests.

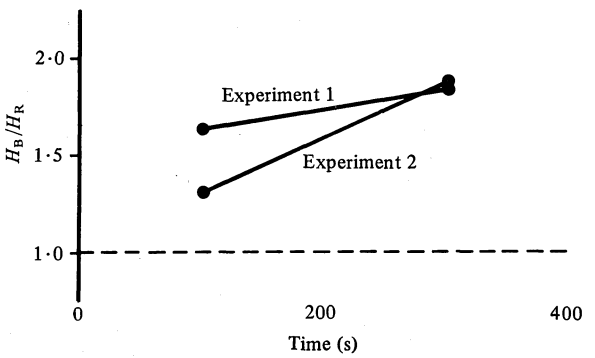

Figure 4. Ratios of mean hold time for blue to mean hold time for red within experiments 1 and 2 (pooled results for all five monkeys).

In fact they pressed the button both for blue when the screen was red and for red when the screen was blue. The left part of figure 5 shows the mean hold times for red and for blue. The right part shows the mean times spent passively between presses—a measure which is hereafter called the 'latency'. For all monkeys the mean hold time for blue (H_B) was greater than that for red (H_R) throughout the test; moreover, for all monkeys the mean latency for blue between presses for red (L_B) was greater than the mean latency for red between presses for blue (L_R). Figure 6 shows the ratio of the hold time for blue to the hold time for red and the ratio of the latency for blue to the latency for red, at corresponding points of the test. Apparently colour had exactly the same effect upon latency as it did upon hold time.

The latter finding is true not only for the monkeys taken as a group but also for the individual subjects. Figure 7 demonstrates this and also brings out another feature of interest. Here the product of the latency for blue and the hold time for red ($L_B H_R$) is plotted against the product of the latency for red and the hold time for blue ($L_R H_B$). In this case the mean values over the whole test have been used. The graph shows that, near enough, $L_B H_R = L_R L_B$ and hence $L_B/L_R = H_B/H_R$ for each individual subject. What the graph also shows is that this relation holds true even though the absolute values of L_B, H_R, etc (and hence their product) were very different for different subjects.

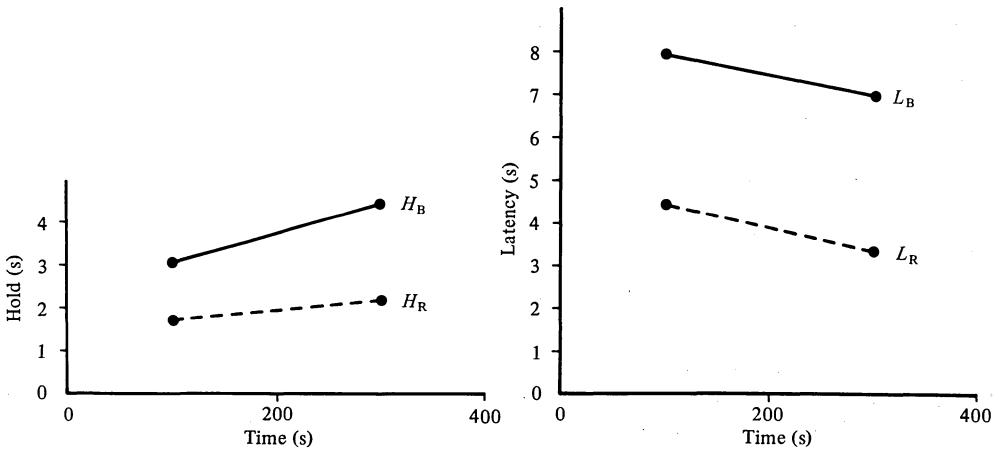

Figure 5. Mean hold times and latencies over the course of the test in experiment 3 (pooled results for all five monkeys). H_B and L_R were measured in the 'press for blue' tests; H_R and L_B were measured in the 'press for red' tests.

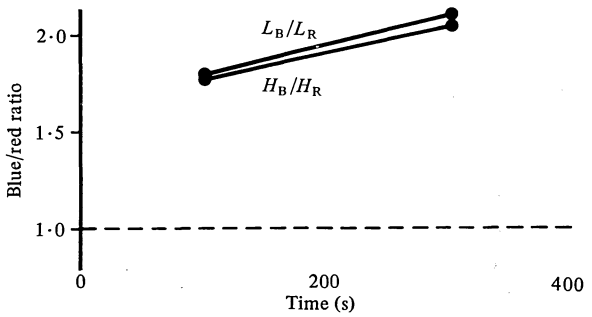

Figure 6. Ratios of mean H_B to mean H_R and of mean L_B to mean L_R within experiment 3 (pooled results for all five monkeys).

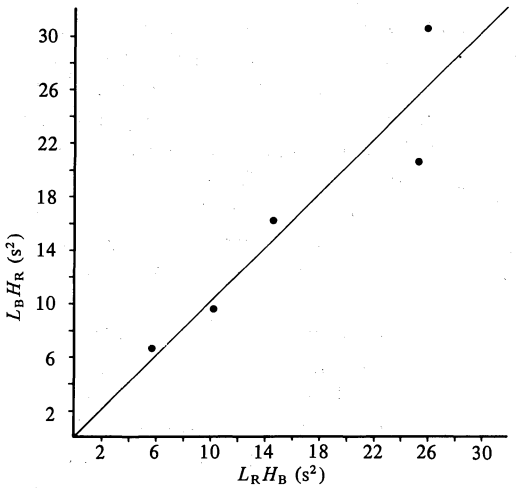

Figure 7. Results for individual monkeys in experiment 3.

6 Discussion

At the simplest level of description the results of the three experiments can be summarised as follows: whatever the monkeys were about to do next—whether to press the button or to let it go—they did it faster in red light than in blue. Thus in all three experiments, once the monkey had pressed the button, he released it again faster when the screen was red than when it was blue (hence $H_B > H_R$); and in experiment 3, once the monkey had released the button, he pressed it again faster when the screen was red than when it was blue (hence $L_B > L_R$).

Consider three possible explanations of this effect of colour on the timing of behaviour.

6.1 *Hypothesis 1*

Monkeys find red light less pleasant than blue, and hence choose to spend less time with it.

6.1.1 *Comment.* In this case one might expect that the colour effect would have been much stronger in the 'choice' situation of experiment 1 than it was in the 'no-choice' situation of experiment 2; but the evidence for this (figure 4) is not convincing. Moreover, one might expect that the monkeys would have refrained altogether from pressing the button to change the screen from blue to red in experiment 3; but in fact they did so frequently. The only obvious way of saving this hypothesis would be to assume that there were strong transfer effects between the different experiments.

6.2 *Hypothesis 2*

Monkeys are more highly 'activated' in red light than in blue, and hence less likely to persist with what they are doing.

6.2.1 *Comment.* This is consistent with the evidence. But it is less than adequate to explain the remarkable results of experiment 3. Why should a change in activity level have had exactly the same effect on latencies as on hold times? Given that the motor behaviour involved in pressing the button (to give the hold times) was very different from the motor behaviour involved in *not* pressing the button (to give the latencies), there is no *a priori* reason to suppose that hold times and latencies should have covaried as a function of activity level. Indeed, in the one circumstance where

it seems likely on other grounds that changes in activity level might have been occurring, namely as the test itself progressed in time, the two measures changed in opposite directions: as figure 5 shows, while hold times went up over the course of the test, latencies went down.

6.3 *Hypothesis 3*
Monkeys have a subjective time clock which runs faster in red light than in blue.

6.3.1 *Comment.* This, although the most far-fetched hypothesis, is in some ways the most powerful. To account for the colour effect in all three experiments it requires merely one realistic extra supposition. Suppose that, within each experiment, the monkey behaved in such a way that *it seemed to him* that he maintained the same temporal pattern of responding independently of the colour on the screen. Then, if his subjective clock was running faster in the presence of red light than blue, he would unwittingly have ended up behaving asymmetrically with respect to the two stimuli, spending less time with the red than the blue. And this would make sense of the quantitative similarity between the ratios L_B/L_R and H_B/H_R in experiment 3. For if, say, the monkey's subjective clock ran p times as fast in red light as in blue, then while intending to maintain *equal* holds and *equal* latencies he would in fact have made $H_B = pH_R$ and $L_B = pL_R$; hence $L_B/L_R = H_B/H_R = p$. Such analysis suggests that the value of p in experiment 3 was approximately 2·0 (for individual monkeys it ranged from 1·5 to 2·2); in experiments 1 and 2 the value was slightly lower.

It would be easier to weigh up these three hypotheses if one knew more about the monkeys' intrinsic motivation. Why did they press the button so consistently? And why, once pressing, did they let go again so quickly? The obvious answers, namely that the monkeys pressed the button in order to provide visual stimulation and interrupted their presses in order to *change* the stimulation, are probably correct but do not give the whole story. It should be emphasised that the rhythm of pressing and releasing which characterised the monkeys' behaviour in all three experiments was in no way mechanically imposed by the apparatus but represents a self-imposed behavioural strategy. We found in earlier 'preference' studies that monkeys resort to this pattern of pressing no matter what the stimuli, equally with cartoon films and with plain white light. It is tempting to read into such behaviour a strategy for periodically sampling the visual environment—as if the presses represent a kind of 'manual saccade'.

The idea that the monkeys were engaged in some kind of visual sampling does not, however, rule out any of the three hypotheses relating to colour. Thus, sampling time might well be affected as much by the degree of liking for the stimulus as by activity level or by the setting of a subjective clock. It may, indeed, prove hard to devise any knockdown experiment to sort out the three hypotheses. Perhaps it will turn out to be impossible, for it is conceivable that, at a causal level, the three hypotheses represent a set of 'nested' propositions. For example—to suggest just one potential causal chain—a faster clock might lead to greater activity which might lead to a feeling of displeasure.

But it would be a pity to call the game a draw just yet. As things stand on the basis of the present experiments the 'subjective clock hypothesis' is clearly in the lead on points. It is also, to borrow another boxing epithet, indubitably the prettiest hypothesis.

Acknowledgements. This work was supported by the Science Research Council. We are grateful to Jeremy Cherfas, Robert Seyfarth, Dorothy Seyfarth, and Pat Bateson for their helpful criticism.

References
Humphrey N K, 1971 "Colour and brightness preferences in monkeys" *Nature* **229** 615-617
Humphrey N K, 1972 "Interest and pleasure: two determinants of a monkey's visual preferences" *Perception* **1** 395-416
Humphrey N K, Keeble G R, 1975 "Interactive effects of unpleasant light and unpleasant sound" *Nature* **253** 346-347