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Effects of a benzodiazepine, lorazepam, on motion integration and segmentation: an effect on the processing of line-ends?

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Abstract

Previous studies have shown that the perceptual integration of component motions distributed across space is inhibited whenever segmentation cues, such as line-ends, are salient. Herein, we investigate to what extent enhanced inhibition induced by lorazepam, a benzodiazepine facilitating the fixation of GABA on $GABA_A$ receptors, modifies the balance between motion integration and motion segmentation at the behavioural level. Motion integration was tested in 16 healthy volunteers taking a single and oral dose of either placebo or lorazepam (0.038 mg kg^{-1}). The stimulus consisted of an outlined diamond presented behind four, otherwise invisible, apertures and translating along a circular trajectory (Lorenceau & Shiffrar (1992). *Vision Research*, *32*, 263–273). Under these conditions, recovering the global diamond direction requires the integration of the component motions available within each aperture. The observers were asked to discriminate the global, clockwise or counter-clockwise, diamond direction under difficult—at high luminance contrasts—or easy—at low luminance contrasts—conditions. Overall, reaction times and error rates increased in the lorazepam group as compared to the placebo group, suggesting strong non-specific effects. However, the changes in performance in the lorazepam group are not homogeneous across conditions, suggesting that lorazepam also induces specific effects that modulate the integration/segmentation balance. Additional experiments performed with visible apertures or visible diamond vertices indicate that the effects of lorazepam are unlikely to reflect a deficit of motion processing or motion integration mechanisms since performance is only slightly impaired in the lorazepam as compared to the placebo group under these conditions. These results suggest that lorazepam might specifically modulate the saliency of line-ends, presumably because processing these features involves inhibitory mechanisms using GABA as a neuromediator, and in turn modify the balance between motion integration and segmentation.

Keywords: Motion Integration; Aperture problem; Benzodiazepine; GABA

1. Introduction

The use of benzodiazepines such as lorazepam is widespread in many countries. Although the mechanisms by which lorazepam acts on the central nervous system are known to involve the GABA neurotransmittor, which largely contributes to visual processing at various stages (Bolz & Gilbert, 1986; Norton & Godwin, 1992; Sillito, 1992; Morin & Molotchnikoff, 1994), the effects of lorazepam at the perceptual level have not been thoroughly studied. The target of lorazepam is the benzodiazepine fixation site which is part of the $GABA_A$ receptors. Lorazepam has no effect on $GABA_B$ or $GABA_C$ receptors. Moreover, it has no direct effect on the GABA receptor but acts only in the presence of GABA and potentiates its effect (Hill & Bowery, 1981; Drew, Johnston & Wheatherby, 1984; Johnston, 1994; Mohler, Benke, Benson, Lüscher & Fritschy, 1995; Smith & Olsen, 1995).

In the present study, we used lorazepam in a neuropsychological-like approach to dissociate the different effects of lorazepam on visuo-perceptual processes. Given the relative specificity of the pharmacological action of lorazepam, this approach may provide insights into the functional role of $GABA_A$ connections at the behavioural level and help to relate electrophysiological studies to perceptual processes.

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This approach has already been used to dissociate the different effects of lorazepam on sedation, on the processing of spatial frequencies, on contour integration or attentional processes (Giersch, Boucart, Speeg-Schatz, Muller-Kauffmann & Danion, 1996; Giersch, Boucart & Danion, 1997). It was discovered that perceptual tasks requiring the integration of contours from static stimuli like fragmented, compound letters or fragmented pictures, are particularly affected by lorazepam (Giersch, Boucart, Danion, Vidailhet & Legrand, 1995; Giersch et al., 1996, 1997; Giersch (in press)). The results from these studies were consistent with the hypothesis that lorazepam acts by facilitating the processing of segmentation cues, such as line-ends. Herein, we attempt to generalize these findings to determine to what extent the balance between motion integration and motion segmentation is affected by lorazepam. Indeed, recovering the motion of objects requires that the local responses from cortical neurons to an input image are bounded together. Although the distributed architecture of the primary visual cortex calls for integration processes, spurious associations between features belonging to different objects must also be avoided, implying that segmentation processes are also involved. It has been argued that both processes work in a cooperative/competitive way (Grossberg & Mingolla, 1985; Peterhans & von der Heydt, 1989; Heitger, Rosenthaler, von der Heydt, Peterhans & Kubler, 1992; Gove, Grossberg & Mingolla, 1995) and heavily rely on line-ends processing (Shimojo, Silverman & Nakayama, 1989; Lorenceau & Shiffrar, 1992).

Experimental evidence (Biederman, 1987; Shimojo et al., 1989; Bregman, 1990; Shimojo & Nakayama, 1990; Lorenceau & Shiffrar, 1992; Stoner & Albright, 1992) suggests a straightforward distinction between features produced by accidental occlusion and features that intrinsically belong to objects (Fig. 1). The former do not intervene in visual segmentation whereas the latter signal real contour discontinuities and strongly constrain the parsing of the retinal image into distinct entities (Nakayama, Shimojo & Silverman, 1989; Stoner, Albright & Ramachandran, 1990).

To determine whether lorazepam influences the integration and segmentation of component motions, we used aperture stimuli and manipulated the status, extrinsic or intrinsic, of line-ends that occur at apertures' borders. Using this class of stimuli, Lorenceau and Shiffrar (1992) found that motion integration is easy whenever the line-ends are extrinsic or when their salience is reduced (e.g. at low luminance). On the other hand motion integration is difficult whenever the line-ends are intrinsic (e.g. when the apertures are invisible).

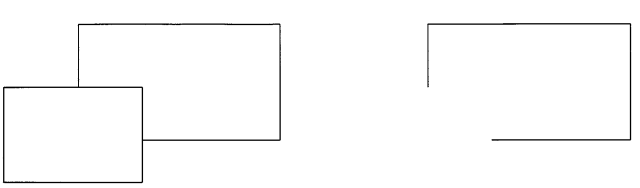

Fig. 1. Examples of intrinsic line-ends (on the left) and extrinsic line-ends with T occlusions (on the right).

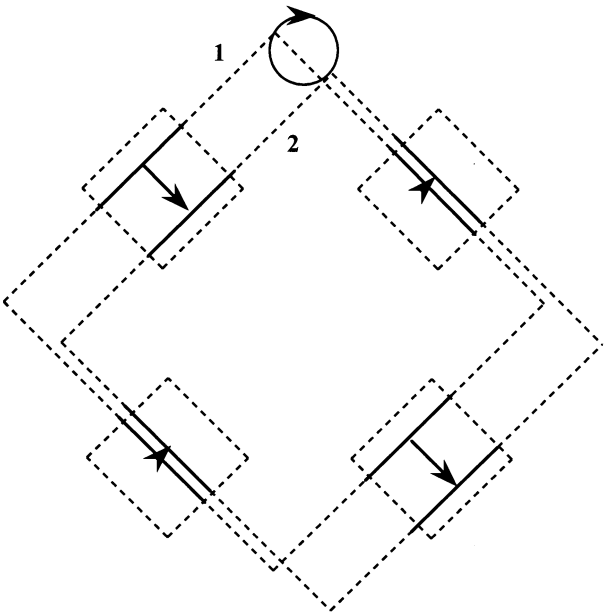

Fig. 2. A diamond seen through four, otherwise invisible, rectangular apertures translates along a circular path in a clockwise or counter clockwise direction, such that only four line-segments are visible. Two frames of an animation sequence are shown. Integrating motion components are required to recover the global diamond's direction.

In the present experiments, we used a display consisting of a diamond outline visible through four invisible stationary apertures such that the diamond's edges were visible, but its corners were hidden. Under these conditions, a circular motion -clockwise or counter-clockwise of the diamond results in local segments motions which may differ from the global motion. In particular, the motion of line-ends at aperture borders, straight and parallel to the borders, is inconsistent with the clockwise or counter-clockwise diamond trajectory (Fig. 2). Lorazepam could affect motion integration performance in a variety of ways: it could decrease contrast sensitivity (Harris & Phillipson, 1995) or impair eye movements (Fafrowicz, Unrug, Marek, van Luijtelaar, Noworol & Coenen, 1995; Hopfenbeck, Cowley, Radant, Greenblatt & Roy-Byrne, 1995). Benzodiazepines might also affect the processing of orientation or direction (Sillito, 1975; Berman, Douglas & Martin, 1992; Bradley, Qian & Andersen, 1995; Somers, Nelson & Sur, 1995). Note that these different potential effects are non-specific, in the sense that they should affect similar experimental conditions that yield easy or difficult motion integration. To isolate a specific effect of lorazepam on motion integration, one must ensure

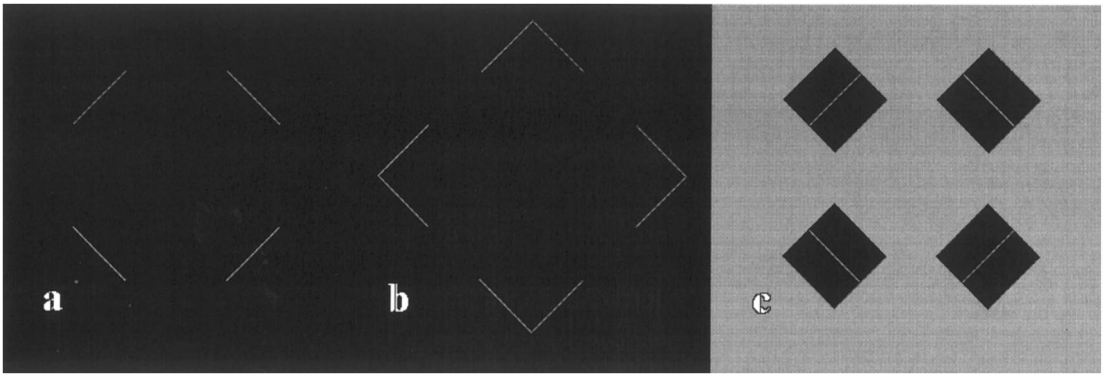

Fig. 3. (a) In the 'invisible apertures' experiment, the four apertures are arranged so that only four gray line-segments are visible on the black background. (b) In the 'visible corners' experiment, the four sides are masked and only the corners are visible. (c) In the 'visible apertures', the four apertures again mask the corners but are visible. Four gray line-segments are seen through four black apertures, displayed against a grey background.

that non-specific effects of lorazepam are negligible or use an experimental design that permits comparisons between a reference baseline and test conditions. We adopted the following experimental strategy: firstly, we measured absolute detection thresholds and motion coherence thresholds before and after lorazepam uptake. The former permits one to determine whether the visibility of the stimuli is affected by the intake of lorazepam. The measure of coherence thresholds—the highest contrast which still induces a coherent percept—permits one to estimate the effect of lorazepam on motion integration. If both thresholds are similarly affected by lorazepam, this would suggest that coherence thresholds depend upon contrast sensitivity. If on the other hand both thresholds are differently affected this would suggest that lorazepam has a specific influence on motion integration. Secondly, we used a 2AFC procedure to measure direction discrimination performance as a function of luminance contrast, using a short duration of motion. Indeed, previous studies demonstrated that simple contrast manipulations deeply change motion interpretation while maintaining the same retinal motion. If lorazepam impairs fixation or eye movements, performance should be similarly affected under the different contrast conditions, while a specific influence of lorazepam should differentially modify performance. We also measured direction discrimination using a diamond with visible corners which provides a reference baseline to estimate the non-specific influences of lorazepam on performance (Fig. 3). Under these new conditions, the integration of component motion across space is not required to perform the task since the motion of a single corner is sufficient to determine the diamond's direction. If lorazepam impairs the processing of direction, lorazepam-treated subjects should be impaired in all conditions. Finally, we used a diamond moving behind visible apertures (Fig. 3). Changing aperture visibility shifts the status of line-ends from intrinsic to extrinsic. If motion integration processes are affected, performance should also be impaired when the apertures are visible, since the integration of component motions is necessary to perform the task under these conditions. In contrast, if lorazepam specifically modulates the contribution of intrinsic line-ends to the integration and segmentation of local motion, there should be no degradation of performance at high luminance in lorazepam-treated subjects, since extrinsic line-ends are thought to be discarded from the integration processes (Shimojo et al., 1989).

2. General methods

2.1. Subjects

In total 16 healthy volunteers (11 women and 5 men) were recruited in the University of Strasbourg. The protocol was approved by the Faculty Ethics Committee. All subjects gave their written informed consent. They were paid 1000FF for their participation.

The subjects had no medical illness or history of alcoholism, drug abuse or tobacco consumption of more than ten cigarettes per day. They were not chronic users of benzodiazepines and had not taken any medication for at least 15 days. They were instructed to abstain from beverages containing caffeine or alcohol for the 24 h prior to the study. The drug was administered to the subjects in the morning, after an overnight fast.

2.2. Experimental design and drugs

Subjects were randomly assigned to one of two parallel groups, of eight subjects each: a placebo group and a lorazepam (0.038 mg kg^{-1}) group. The drug capsule was given orally using a double-blind procedure. The

experiments were conducted the day before the intake of the drug and subjects were investigated again between 1.3 and 3 h after the intake of the placebo or lorazepam capsule. All subjects were tested with optical correction. The presentation of the stimuli was always monocular to avoid any contamination of the results by a lorazepam induced impairment of the oculomotor balance (lorazepam does not affect visual acuity nor accommodation; Giersch et al., 1996).

2.3. Apparatus and stimuli

The stimuli were displayed on a 21′ colour video monitor (IDEK 53021). They were generated through a micro-computer equipped with a GEMINI graphic card. The screen resolution was 1024×1280 pixels (60 Hz, 8 bit/pixel). The viewing distance was 114 cm. Subjects had their head maintained by a chin rest with a forehead support and gave their response by pressing the right or left arrow of the computer keyboard.

The stimulus was a centrally displayed diamond (whose side length was 3.8° of visual angle) translating in a clockwise or counter-clockwise direction along a circular path (path radius of 0.3°). A central red fixation point was present throughout the experiments. The trajectory starting point was randomly chosen among eight possibilities, separated by 45° steps. The direction of translation, either clockwise or counter-clockwise was randomly chosen on each trial. The inter-trial interval was fixed at 1000 ms after the execution of the response.

During the threshold measurements, the diamond, whose luminance was chosen at random, moved continuously along a circular trajectory. It was visible through four invisible squared apertures (1.3×1.3° of visual angle) and only four straight edges of the diamond were visible. Since background luminance was kept at 0.02 cd m^{-2}, contrast increased with increasing diamond luminance. The subjects used the right and left mouse buttons to adjust the luminance, either to just detect the presence of a stimulus, independently of its motion, or to determine the maximum luminance which yields a coherent motion (i.e. higher luminance would result in incoherent segment motion). When the subjects were satisfied with their settings, the response was recorded and the stimulus was cleared. Measures were repeated 20 times.

In 2AFC experiments, the diamond translated along a circular path for 150 ms (about 1/6 of a cycle). On each trial, the diamond's luminance (1, 1.5, 3, 6, 12.5, and 25 cd m^{-2}) was chosen at random. Each experiment included a total of 240 trials (40 trials per condition) in two blocks of 120 trials. The subjects, informed that the four visible elements were part of a diamond, were instructed to discriminate the global diamond's direction -clockwise or counter-clockwise and to respond as accurately and rapidly as possible by pressing on the right or left arrow of the keyboard. No feedback was given to the subjects during the experiments. (1) When apertures were invisible and masked the corners of the diamond, only straight line-segments moved against a dark background (0.02 cd m^{-2}) ('invisible apertures' experiment). (2) The 'visible corners' experiment differed from the 'invisible apertures' experiment in that the four static apertures masked the sides of the moving diamond. Only the diamond corners were visible. (3) The 'visible apertures' experiment differed from the 'invisible apertures' experiment in that four dark apertures (luminance 0.02 cd m^{-2}) were presented against a grey background (1 cd m^{-2}) (Fig. 3).

2.4. Procedure

The subjects started with a training session the day before the intake of the placebo or lorazepam capsule. They had to decide whether a diamond, whose corners were visible, moved clockwise or counter-clockwise. The practice session was stopped when performance was higher than or equal to 75% correct response at the end of a block of 40 trials. Subjects had then performed a complete experimental session, which was repeated on the day of the capsule intake. In the two experimental sessions, each experiment was preceded by a 20 trials training session. The order of the experiments was randomized across subjects in each treatment group, but was the same for each subject before and after the intake of the placebo or lorazepam capsule.

2.5. Analogue self-ratings of sedation

Subjects assessed their subjective feelings before and 1.5 h after the intake of the placebo or lorazepam capsule. They used a set of 15 visual analogue scales derived from Bond and Lader (1974). Each scale consisted of a 100 mm horizontal line without gradation, anchored by contrasting states of mind. Subjects were asked to regard each line as a continuum and to rate their feelings by placing a vertical mark across each line. The ratings were measured as the distance in millimetres between the positive end of each line and the subject's mark. Five scales were used to assess complementary aspects of sedation (alert–drowsy, excited–calm, clear headed–muzzy, energetic–lethargic, fast–slow). The mean score of these five scales was calculated for each subject, before and after the intake of the drug. A sedation index was calculated by dividing the difference in scores observed before and after the intake of placebo or lorazepam by the score observed before the intake of the drug capsule.

2.6. Analysis of results

No difference in performance was observed between treatment groups before the intake of the placebo or lorazepam capsule. The results observed before treatment reproduced those published in Lorenceau and Shiffrar (1992). We shall hence focus our analysis on the comparison of performance before and after the intake of the drug capsule in the two treatment groups.

As lorazepam has sedative effects, some lorazepam-treated subjects had temporary lapses in vigilance. The frequency of these lapses was between 0 and 10 in one experiment, depending on the lorazepam-induced sedation. These lapses induced increased RTs. Hence, we discarded the highest RTs in the results, so that less than 2% of the data were discarded in the lorazepam group.

3. Results

3.1. Detection and coherence thresholds

Analyses of variance were conducted on the detection thresholds and on the coherence thresholds, with subjects as a random variable. There was one between-subject variable, the treatment, and one within-subject variable, the day of test (before or after treatment). The results, averaged over subjects and direction of motion, are displayed in Fig. 4.

Before treatment, the averaged detection threshold is 0.18 cd m^{-2} ($\pm$ 0.05 SD) and the coherence threshold is 0.67 cd m^{-2} ($\pm$ 0.59 SD). After the intake of the drug, the detection threshold increases by 0.09 cd m^{-2} in the lorazepam group ($F[1, 7] = 8$, $P < 0.05$) and decreases by 0.01 cd m^{-2} in the placebo group ($F < 1$). In contrast, the coherence threshold remains stable in the two groups ($F < 1$).

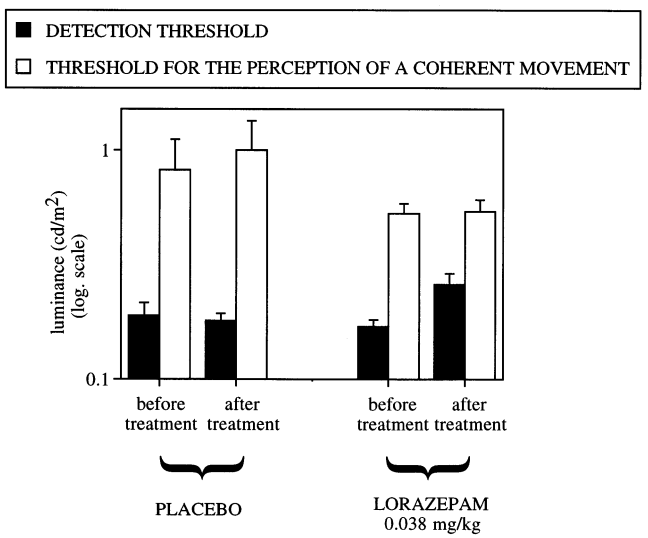

Fig. 4. Detection (black bars) and coherence (white bars) thresholds averaged across observers, before and after treatment, in the placebo and the lorazepam (0.038 mg kg^{-1}) group. Each column represents the mean of 20 measures for the eight subjects of each group.

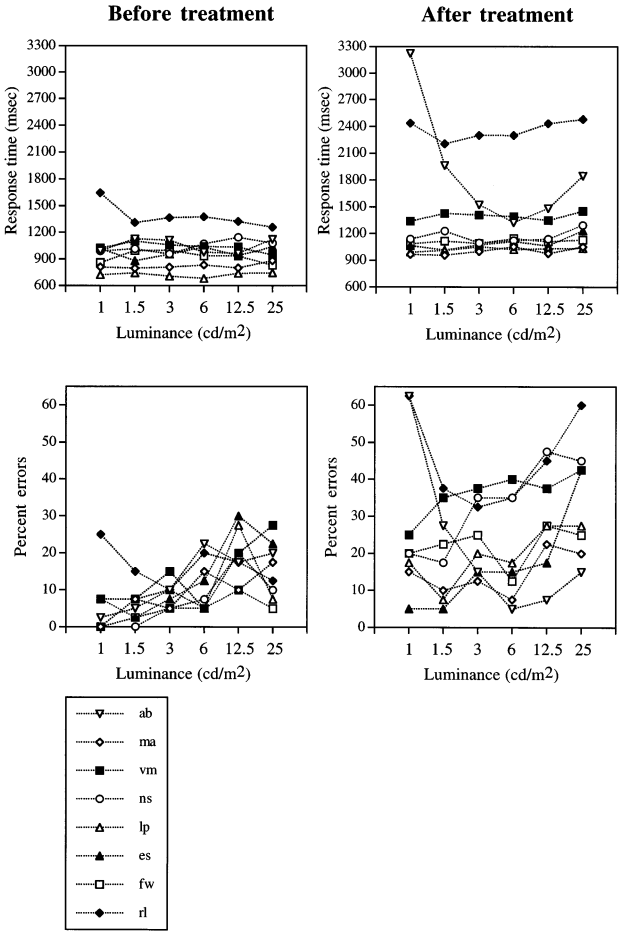

Fig. 5. Correct RTs (upper panels) and errors (lower panels) for each subject in the lorazepam group, in the invisible apertures experiment, before the intake of the drug (left) or after the intake of the drug (right) as a function of the luminance levels (1, 1.5, 3, 6, 12.5 or 25 cd m^{-2}). Each data point represents the mean of 40 measures for one subject.

3.2. 2AFC Experiments

Individual results in the 'invisible apertures experiment' are displayed Fig. 5. As a general trend the error rate increases as the luminance of the segments increases, which replicates previous results (Lorenceau & Shiffrar, 1992). Analyzing individual results indicates that all subjects are impaired at high luminance after the intake of lorazepam whereas an impairment at low luminance is observed in only two subjects.

These two subjects respond at chance level when the diamond's luminance is 1 cd m^{-2} (above 60% errors vs. errors lower than 35% at medium luminance), whereas the other subjects make no more than 25% errors at 1 cd m^{-2}. The same two subjects are also those showing the highest detection threshold in the adjustment

experiment (0.38 and 0.37 cd m^{-2} vs. a mean of 0.22 cd m^{-2} in the other subjects—from 0.15 to 0.29 cd m^{-2}). Since the duration of motion is only 150 ms in the present experiment it is likely that the lowest luminance levels (1 and 1.5 cd m^{-2}) were close or below the detection threshold of these two observers.

At high luminance, these same two subjects made many errors and their RTs were much longer than those of the other subjects. We thus discarded the results of these two subjects from the analysis to ensure that the results observed at high luminance are not simply due to the results of these two observers. However, it is worth noting that all significant effects described in the following three experiments are also significant when all subjects are included in the analysis

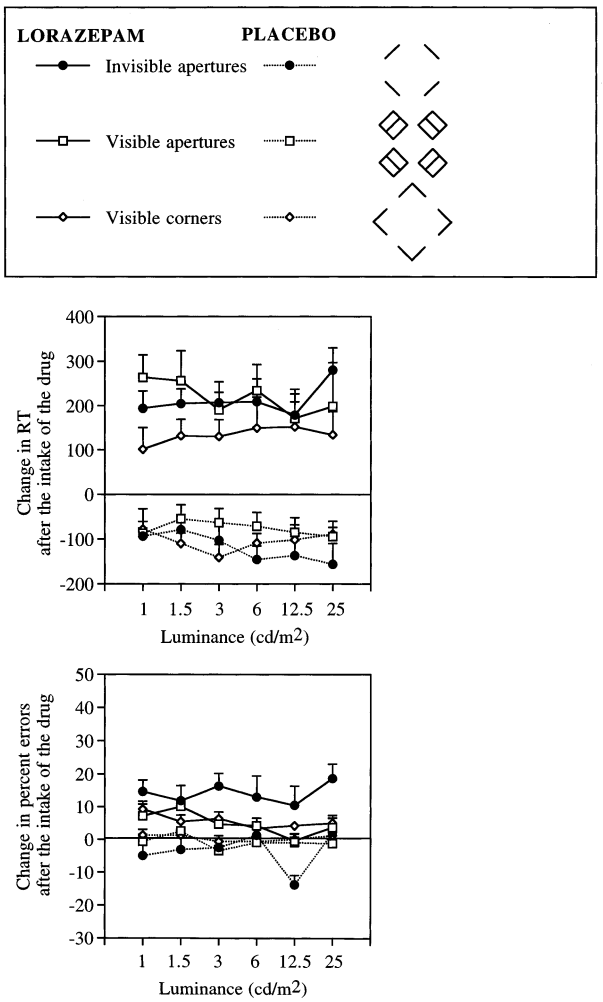

Fig. 6. Mean RTs (upper panel) and errors (lower panel) differences between the two experimental sessions (before and after the intake of the drug) with standard errors (averaged across subjects) as a function of the type of stimulus, line-segments in invisible apertures (black circles), visible apertures (white squares), or visible corners (white diamonds) for six luminance levels (1, 1.5, 3, 6, 12.5 or 25 cd m^{-2}), in the placebo group (dashed lines) and in the lorazepam group (plain lines). Each data point represents the mean of 40 measures for eight subjects in the placebo group and six subjects in the lorazepam group.

and only the four highest luminance levels are considered.

Analyses of variance were conducted on RTs and errors, with subjects as a random variable. The differential results (after vs. before the intake of the drug) of the six remaining subjects are displayed Fig. 6 for each 2AFC experiment.

Before treatment, the mean RTs and the mean error rate across groups and experiments are respectively 881 ms and 7%. In the placebo group, RTs and the error rate decrease on the following day (by 100 ms, $F[1, 7] = 21.5$, $P < 0.005$, and by 1.3%, $F[1, 7] = 1.7$, *ns*). These changes in performance are likely to be explained by an effect of practice and may reflect some form of perceptual learning. Such effect of practice has already been observed in similar experiments (Lorenceau, 1996). In contrast, RTs and errors increase in the lorazepam group on the following day (by 192 ms, $F[1, 5] = 29.2$, $P < 0.005$, and by 8.1%, $F[1, 5] = 21.9$, $P < 0.01$).

Although lorazepam globally degrades performance, either RTs or error rates, this degradation is not equally distributed among the different experimental conditions, and seems to depend on the segment luminance, at least for RTs, as suggested by a significant interaction between the treatment, the diamond luminance, the type of experiment and the day of test-before or after treatment—($F[10, 120] = 2$, $P < 0.05$ for RTs). Further analyses show that this interaction results from the fact that, after the intake of lorazepam, RTs increase more with luminance in the 'invisible apertures' experiment (black circles) than in the two other experiments. Indeed, in the 'invisible apertures' experiment, RTs increase significantly with increasing luminance only after the intake of lorazepam (+ 102 ms, $F[5, 25] = 4.7$, $P < 0.005$), in a linear way (polynomial test of order 1: $F[1, 5] = 16.9$, $P < 0.01$; RTs increase by 43 ms from 1 to 6 cd m^{-2}, $F[1, 5] = 9.2$, $P < 0.05$). RTs do not increase significantly with luminance in the placebo group (+ 60 ms before treatment, $F[5, 35] = 1.4$, *ns* and 1 ms after treatment, $F < 1$) nor in the lorazepam group before the intake of the drug (+ 16 ms, $F < 1$). In the two other experiments, the changes in RTs across experimental sessions did not vary significantly with luminance between the two groups[1] ($Fs < 1.4$). In addition,

[1] In Fig. 6, the change in RT after the intake of lorazepam appears to increase slightly with luminance in the 'visible corners' experiment. However, that was due to the results of one subject only. All other subjects had perfectly flat curves. Concerning the 'visible apertures' experiment, the degradation of performance apparent on the graphic at low luminance was not significant for RTs and only tended to be significant for errors ($F[5, 25] = 2.5$, $P = 0.057$). The changes in RTs at low luminance probably plays only a minor role in the fourth order interaction. This conclusion is supported by the sub-analysis showing that the slope fitted to the data of the lorazepam group (using data from 12.5 and 25 cd/m^2 from the 'invisible apertures' experiment) is steeper than the slope observed in the 'visible corners' experiment ($F[1,5] = 8.4$, $P < 0.05$) and in the 'visible apertures' experiment ($F[1,5] = 8.3$, $P < 0.05$).

the increase of error rates induced by lorazepam is larger in the 'invisible apertures' experiment than in the two other experiments. This results in a significant interaction between the treatment, the type of experiment and the day of test ($F[2, 24] = 8.2$, $P < 0.005$). Consistent with the RT results, this effect is significant at the highest luminance (from 3 to 25 cd m^{-2}) in the lorazepam group ($+14.6\%$ in the 'invisible apertures' experiment vs. $+3.8\%$ in the two other experiments, $F[2, 10] = 7.5$, $P < 0.01$), but not at the lowest contrasts (1 and 1.5 cd m^{-2}) ($+13.1\%$ in the 'invisible apertures' experiment vs. $+8\%$ in the two other experiments, $Fs < 2.2$).

A correlation analysis showed that the increase in the detection threshold is significantly correlated with the sedation index in the lorazepam group ($r = 0.753$, $N = 8$, $P < 0.05$). There is no significant correlation between the sedation index and the performance impairment induced by lorazepam at high luminance, even when all eight subjects are included (Pearson correlation, coefficients $r < 0.27$).

4. General discussion

Using a double blind procedure, we measured the effects of an uptake of lorazepam on performance in a motion integration task. The results can be summarized as follows:

(1) Contrast thresholds for the detection of the diamond stimulus increase under lorazepam conditions, consistent with previous data (Harris & Phillipson, 1995). This effect is positively correlated with the sedation index. (2) Despite increased detection thresholds, the contrast thresholds for global coherence are stable under lorazepam conditions. (3) Lorazepam induces an increase in both RTs and errors in the direction discrimination experiments. (4) The performance degradation in the lorazepam group is larger in the 'invisible apertures' experiment than in the 'visible apertures' and 'visible corners' experiments. These effects are significant at high, but not at low luminance contrasts.

Several aspects of the present results suggest that the effects of lorazepam are different at low and high luminance contrasts. Firstly, sedation is correlated with the increase in the detection threshold, but not with the degradation of performance at high luminance. Secondly, the decrease in performance observed at low luminance is not significantly different across experiments. That lorazepam decreases contrast sensitivity (Blin, Mestre, Paut, Vercher & Audebert, 1993; Maddock, Casson, Lott, Carter & Johnson, 1993; Harris & Phillipson, 1995), suggests that impaired performance at low luminance contrasts results from decreased stimulus visibility. According to Maddock et al. (1993), the effects observed at low luminance would be non-specific, and related to the sedative effect of lorazepam.

At high luminance, the increase in RTs is significantly larger in the 'invisible apertures' experiment than in the other experiments. This effect, which does not result from a speed-accuracy trade-off, is incompatible with the idea that non-specific effects of lorazepam on eye movements, fixation, direction or orientation processing are involved. One might argue that the task is more difficult at high luminance in the 'invisible aperture' experiment, and that the performance degradation in these conditions is due to a sedative effect. However, the effect persists even when the more sedated subjects are discarded from the analysis. The amplitude of the remaining effect ($+102$ ms) can hardly been explained by a simple sedative effect. Moreover, additional experiments which involve experimental conditions of similar difficulty (Giersch (in press); Lorenceau & Giersch (in preparation)) suggest, that the performance degradation induced by lorazepam is not necessarily related to the difficulty of the task. Finally, the hypothesis that motion integration processes are specifically affected can also be ruled out. Indeed, integrating component motions—and thus recovering the local component direction and speed—is necessary to perform the task in the 'visible apertures' experiment. However, direction discrimination performance is slightly less impaired at high luminance than at low luminance under these conditions and is similar to that of the 'visible corners' experiment that does not require the integration of component motions across space. Since the main difference between the 'visible' and 'invisible' apertures conditions lies in the status of the line-ends, extrinsic in the former, intrinsic in the latter, one possible explanation of these effects is that lorazepam specifically affects the processing of intrinsic line-ends. This hypothesis is compatible with the results from previous experiments using static collinear elements suggesting that lorazepam improves the detection of spatial discontinuities (Giersch et al., 1995, 1996, 1997; Giersch (in press)).

With the assumption that lorazepam specifically affects performance in perceptual integration tasks through modulations of line-end salience, it remains to be determined what could be the physiological substrate of these effects. Although numerous physiological studies stressed the fact that lorazepam facilitates the fixation of GABA on the $GABA_A$ receptor and emphasized the role of GABA in visual processing, a discussion of the present results at the light of these physiological studies can only be highly speculative.

One possibility is that end-stopped or hypercomplex cells, commonly found in cat and monkey visual cortex, (Hubel & Wiesel, 1968; Saito, Tanaka, Fukada & Oyamada, 1988; von der Heydt & Peterhans, 1989) are involved. As a matter of fact, these cells respond optimally to short bars or spatial discontinuities and have a poor contrast sensitivity (Hubel & Wiesel, 1965; Orban,

Kato & Bishop, 1979a,b; Duysens, Orban, van der Glas & De Zegher, 1982a; Duysens, Orban, van der Glas & Maes, 1982b; Tanaka, Ohzawa, Ramoa & Freeman, 1987; Saito et al., 1988; Jagadeesh & Ferster, 1990; DeAngelis, Freeman & Ohzawa, 1994). In addition, GABA is likely to be involved in the generation of end-inhibition, as intravenous bicuculline (a $GABA_A$ antagonist) induces an extinction of the end-inhibition properties of hypercomplex cells in the cat (Pettigrew & Daniels, 1973; Rose & Blakemore, 1974).

The hypothesis of a role of end-stopped cells to account for the effects presented herein offers the advantage of a great consistency between the existing physiological literature and our results. However, one cannot exclude other alternative explanations. Lorazepam may increase the weight accorded to the line-ends, or induce an imbalance between discontinuous information and continuous information, but after the processing of line-ends has been carried out. Further electrophysiological studies are needed to distinguish between these hypotheses.

Whatever the precise processing level affected by lorazepam, it is worth noting that although treated subjects are slowed down, they still perform accurately in the motion integration task, suggesting that lorazepam does not induce a visual deficit but rather a modulation in the processing of visual information. A modulatory effect is consistent with a hypothesis in terms of an imbalance between either the processing or the use of discontinuous and continuous information, at the cost of continuous information.

5. Conclusion

Our results, consistent with previous experiments, suggest that lorazepam enhances the processing of line-ends which in turn impairs the integration of component motions across space. As lorazepam has both an effect on the fixation of GABA on the $GABA_A$ receptor and at the behavioral level, we suggest that lorazepam might be used in a neuropsychological-like approach to dissociate the different processes involved in the analysis of sensory information and to establish links between electrophysiology and experimental psychology.

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