

Visual skills and playing positions of Olympic hockey players

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Running title: Visual skills of Olympic hockey players

Keywords: Vision, visual abilities, hockey, vision screening

Summary – Many sports require fine spatiotemporal resolution for optimal performance. Previous studies have compared anticipatory skills and the decision making process in athletes; however, information is lacking on visual skills of elite athletes. To assess visual skills of Olympic hockey players and analyse differences by playing position and to analyse improvement of visual skills after training, 21 Olympic hockey players were pre- and post-tested on 11 visual tasks following a 10-week visual training programme. The lack of mean differences at pre-test between players of different positions suggested visual skills are independent of playing position; however, after training, an improvement was seen in all players with goalkeepers improving significantly more than outfield players.

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Introduction

In any position of any sport, vision provides the athlete with information regarding where, when and what to do. Regardless of physical strength, speed, and technical skill of an individual, ability to quickly and correctly process visual information presented to them can differentiate between elite and non elite performers. This was summed up succinctly by the legendary American Football coach, Blanton Collier (1979) who developed the concept that ‘the eyes lead the body’. It is estimated that 85–90% of sensory information regarding the external environment is obtained visually (Loran & MacEwen, 1995). Considering the speed at which ball games are played nowadays, it seems feasible to state that visual processing in a sport setting is one of the most demanding activities faced by the human visual system.

Previous studies have identified marked differences between elite and nonelite sport performers in a variety of visual skills including dynamic visual acuity (Barnes & Schmid, 2002; Millslagle, 2000), stereopsis (Coffey & Reichow, 1990), saccades (Christenson & Winkelstein, 1988; Zhang & Watanabe, 2005), pursuit (Bahill & LaRitz, 1984), hand-eye coordination (Vogel & Hale, 1992), visual reaction time (Dogan, 2009), peripheral awareness (Zweirko, 2008), speed of recognition (Isaacs & Finch, 1983) attentional processing (Overney, Blanke & Herzog, 2008), and visual field (Berg & Killian, 1995). In team ball sports each position has very different physical, tactical and skill related demands. As with the differences highlighted between elite and nonelite athletes, it could be argued that different positions in ball games might demand different visual skills. It has been shown that various sports require different visual abilities (Dogan, 2009), and it makes sense that visual demands which are position-dependent will vary across players, in particular, in sports where goalkeepers often carry out a very specific role within a team. In field hockey, goalkeepers have to face powerful shots coming towards them at different angles, heights and speeds.

1 Defenders need to be able to watch the player they are marking as well as tracking the ball
2 which could be some distance away. Midfielders should constantly be aware of what is
3 happening around them to select the correct pass and make interceptions, and forwards need
4 to use their skills to avoid a defender's tackle and spot spaces into which they can move.

5 Given the diverse visual tasks to which hockey players are exposed and with further
6 differences experienced when playing positions are taken into consideration, it could be
7 hypothesised that visual demands between positions would differ. In particular, given
8 empirical observations from the coaching community, it would seem that goalkeepers should
9 score better than other players. However, despite the need for understanding visual skills in
10 hockey not only as talent identification but also in performance, few researchers have tried to
11 define visual skills of elite players and understand any differences by playing position.
12 Bhanot & Sidhu (1980) assessed the visual reaction time of 92 hockey players and found
13 defenders had the fastest reaction times and midfielders the slowest. Calder (1999) examined
14 a wide range of visual skills (including peripheral vision, visual reaction time, visual acuity,
15 visual memory, eye movement skills, visual concentration, visual recognition and balance) of
16 elite hockey players and found no significant differences across playing positions. No other
17 study was found in which visual skills of elite hockey players were analysed to assess
18 differences by playing position.

19 While evidence suggests different visual skills for athletes of varying qualification,
20 there is no information on positional differences although such differences are marked in
21 terms of movement patterns. MacLeod, Bussell & Sunderland (2007) examined motion
22 frequency of elite female hockey players and found that defenders spent less time walking,
23 but a greater amount of time in activity of low intensity than forwards and midfielders.
24 Similar positional differences in movement and activity patterns have been observed in other
25 sports including rugby union, football and cricket (Deutsch, Kearney & Rehrer, 2007; Reilly

1 and Thomas, 1976; Petersen, Pyne, Portus & Dawson, 2009). Sports vision-training
2 programmes have been suggested to athletes to improve performance. Although in certain
3 cases it has been seen that specific vision training has not shown improvements in visual
4 acuity and peripheral acuity (Westheimer, 2001; Abernethy & Wood, 2001), vision function
5 and shooting skills were enhanced in Olympic shooters who participated in an unspecified
6 vision training programme lasting approximately 20 hours over a 3-month period (Quevedo
7 & Sole, 1995). Furthermore, West and Bressan (1996) showed improvements in visual skills
8 of cricket players with a vision training programme involving seven skills. Similar
9 improvements have been reported for college basketball players (Kofsky & Starfield, 1989)
10 and varsity soccer players (McLeod, 1991). It is possible that, if a large number of repetitions
11 were used to coach a particular visual skill, a significant improvement in visual performance
12 could be obtained (For review see Ciuffreda & Wang, 2004, and Williams & Grant, 1999).

13 Athletes are assigned to specific playing positions during the course of their athletic
14 development given a variety of abilities and anthropometric characteristics. Limited
15 information is available on their visual skills and notably is lacking on the trainability of such
16 skills by playing position. The primary aim of this work was therefore to provide a
17 comprehensive assessment of visual skills of elite hockey players and to analyse the
18 differences between playing positions. A secondary aim was to verify the effectiveness of a
19 vision training programme with particular reference to differences in playing positions.

20

21 Method

22 *Participants*

23 Twenty-one male international hockey players (mean age 25.4, SD = 5 years)
24 participated in a sports vision-training programme. All were members of the Olympic team.
25 Participants were split into groups depending on their playing position for the national team

1 (Goalkeepers, = 3; Defenders, = 6; Midfielders, = 6; Forwards, = 6). All participants gave
2 informed consent, and all procedures complied with the University of Surrey ethical
3 guidelines.

4

5 *Testing Task*

6 The six computer-based visual tasks are described as follows:

7 Dynamic Shape Recognition involved watching a row of arrows move rapidly across the
8 screen and pressing the cursor key (with their preferred finger on their dominant hand)
9 matching the direction that each arrow was pointing. For example, the arrows were scrolling
10 from left to right across the screen, and the participant had to respond starting with the
11 uppermost arrow and work downward (see Figure 1a). In this case, the correct sequence was
12 to press the right-pointing cursor key, then the right again, then down, two more right, down
13 twice, left, etc. Following each key press, the arrow being responded to disappeared.

14 <FIGURE 1 ABOUT HERE>

15 Rotational Acuity involved watching a series of Landolt Cs rotate in rings around a
16 central point and detecting where the opening in each was. Adjacent rings rotated in opposite
17 directions. For example, there were four rings each made up of five or six Landolt Cs (see
18 Figure 1b). Participants responded from the inner most ring first, starting with a green
19 coloured circle. The task was to press the arrow key corresponding to the position of the
20 opening in the Landolt C. For this example the correct responses for the first ring were right,
21 right, down, right, left, up.

22 Saccadic Eye Movements were measured when a Landolt C appeared at a random
23 location on the screen and disappeared after 250 m/sec. Participants had to move their eyes
24 quickly to the C and recognise where the opening was. Immediately following the response,
25 another C appeared elsewhere on screen. In the example shown in Figure 1c, a participant

1 had to press the right arrow key and then another C would appear. This tests saccadic eye
2 movements as participants had to move their eyes very quickly between locations and focus
3 on the Landolt C to detect where the opening lay in each.

4 For Peripheral Awareness nine shapes, arranged in a 3x3 square, appeared on the screen
5 for 200 m/sec. The shape in the centre of the grid matched one of those surrounding it, and
6 participants had to locate the matching shape by using the number pad on the side of the
7 keyboard. In the example shown in Figure 1d, the correct response was to press the number 9
8 key on the grid as the matching shape was in the top right hand corner. The correct answer
9 for Figure 1e was the number 8 key as the matching shape was in the top middle position.
10 The short stimulus duration ensured that participants had to focus on the central shape and
11 use their peripheral vision to detect which of the surrounding shapes matched. The size of the
12 grid varied so peripheral awareness at different visual eccentricities was trained. The overall
13 display size was $25^{\circ} \times 16^{\circ}$ and the furthest symbol was 13° from fixation placing it in the
14 visual periphery.

15 Focus Acuity was measured in a similar way to rotational skills but with the Landolt Cs
16 rotating in an orbital path rather than in two-dimensional rings (see Figure 1f). Participants
17 started with the innermost ring and again responded using the arrow keys to show where they
18 thought the opening in the Landolt C appeared. Because the Landolt Cs appeared to move
19 from near to far the participants' eyes had to track them through various apparent depths.

20 For Dynamic Visual Acuity, a chain of Landolt Cs moved around the screen in a snake-
21 like manner (see Figure 1g). Participants had to detect the opening of each C as these moved
22 around, starting with the 'leading' end of the snake. This task forced participants to keep the
23 Landolt Cs in focus so that the opening could be detected, whilst the Cs were moving around
24 unpredictably.

1 Each of these tasks had 30 levels with increasing difficulty (difficulty increase by
2 variously by increasing the speed at which a target moved, reducing the time a target was
3 visible for, changing the background to make the target less obvious); the testing was carried
4 out on Level 21 (out of 30 – with Level 1 being the easiest level and 30 being the most
5 difficult). Each level had ten repetitions to make the complete test. In order to progress to the
6 next level an athlete had to score 90% or over the ten repetitions. Score was calculated by
7 number of correct responses in the allocated time. Athletes had a maximum of 20 second to
8 complete each individual repetition and then there was a five second break before the next
9 repetition began.

10 The five practical tasks are described now and in the order in which they were
11 administered:

12 For Horizontal Saccades (HORSAC) two 10x10 Snellen letter-acuity charts were placed
13 side-by-side one metre apart at eye level on the wall. Participants stood one arm's distance
14 from the wall, lined up centrally between the charts and, keeping the head as still as possible,
15 read letters alternately from each chart. The score was the number of correct letters read in
16 one minute.

17 Vertical Saccades was the same as Horizontal Saccades but with the letter charts placed
18 vertically one above the other rather than side-by-side.

19 For Focus Flexibility participants stood three metres from a 10x10 letter chart displayed
20 at eye-level. They held in their hands another 10x10 chart and read alternate letters from the
21 near and far charts. The score was the number of letters correctly read in one minute.

22 The Rotator Board test required a circular board with a diameter of 30 cm to be spun on a
23 turntable at a speed of 2 sec./ rotation. The board had each letter of the alphabet randomly
24 printed on it with a hole alongside (see Figure 1h). Participants had one minute to place a

1 golf-tee in the hole beside each letter in alphabetical order. The score was the number of
2 letters each successfully completed within the minute.

3 During the Recognition Task participants watched a number of short film clips, and after
4 each clip answered a question related to what they had seen. Questions were designed to
5 assess several different areas of visual activity, including eye movements, speed of focusing,
6 depth perception, fixation ability, colour perception, and visual memory. For example,
7 participants were asked questions such as how many characters they could count, what
8 appeared on a wall, and which of two characters was farther away.

9

10 *Testing Protocols*

11 Participants performed the tests in two testing sessions separated by 24 h but in the
12 first testing session participants performed the computer tasks; in the second one they
13 performed the practical tasks.

14

15 *Training Programme*

16 The players took part in a ten-week training programme during the build-up to their
17 qualification for, and participation in, the Beijing 2008 Olympic Games. The training
18 programme consisted of six computer-based exercises which the players practised three times
19 per week for 20 minutes per session and four practical exercises which were practised for one
20 hour per week.

21 The computer-based training was provided on the six previously described exercises.
22 The players began on Level 1 and once they achieved over a 90% success rate, they could
23 progress to the next level. Each level became more difficult through a combination of shorter
24 time limit, shapes/Landolt Cs appearing for a shorter period of time, and items moving
25 around the screen more quickly. The four practical exercises for which training was given

1 were the Horizontal Saccades, Vertical Saccades, Focus Flexibility, and Rotator Board.
2 Different stimuli were used for training and testing.

3 Testing was repeated at the end of the training programme with the same protocols
4 except for the Recognition task. No specific training was given for this task, and there were
5 two separate sets of clips, half the participants saw Set 1 at pre-test and Set 2 at post-test; the
6 other participants saw Set 2 at pre-test and Set 1 at post-test.

7

8 *Statistical Analysis*

9 All data are presented as mean \pm standard error of measurement. Comparisons
10 between athletes grouped by playing positions were performed using Anova with Tukey's
11 *post hoc* tests. The correlations between scores on the visual skills tests were analysed using
12 the Pearson product-moment correlation coefficient. A 3-way Anova with playing position as
13 the between subjects variable and time (pre- or post-test) and task as the within subjects
14 variable was used to analyse the effects of the training programme. Alpha was set at .05.

15

16

Results

17 Before any training had taken place no statistically significant differences ($>.05$)
18 were found among playing positions and or among the visual tasks (see Table 1).

19

20

< TABLE 1 ABOUT HERE >

21

22 The Pearson product-moment correlations among tasks are was carried out and found
23 a moderate to large relationship between scores on Horizontal Saccades with those on
24 Vertical Saccades (.75 [$<.05$]), but no other scores for these tasks were correlated.

1 time, task, and position $F(3,17) = 1.85$; $p < 0.01$, partial $\eta^2 = 0.246$, observed power = 0.994.

2 This interaction effect shows that improvement varied by position as well as task. Figure 5

3 shows the percent improvements for each position separately for the each task.

4 <FIGURE 5 ABOUT HERE>

5

6 Discussion

7 The initial data comparing results by position is supportive of the previous work by
8 Calder (1999) in showing no statistically significant differences between players' positions
9 across the range of visual skill tasks. This finding, together with the numerous studies in
10 which expert athletes demonstrate superior visual skills to novice athletes (e.g., dynamic
11 visual acuity by Barnes & Schmid, 2002; saccadic eye movements by Christenson &
12 Winkelstein, 1988; stereopsis by Coffey & Reichow, 1990; peripheral awareness by Zweirko;
13 2008), is consistent with the possibilities that either to reach this elite level of play athletes
14 have superior innate visual skills or that playing sport at a high level increases visual skills of
15 all individuals. It is the faster, more demanding pace of the game that requires players show
16 such increases rather than differences in the specific visual demands faced by individuals in a
17 playing position.

18 Unlike previous studies, in which positional differences have been examined only
19 without visual training, retesting the same participants was included here and scores by
20 position after a 10-week visual training programme showed significant improvements across
21 all participants from pre-test to post-test. One may conclude participation in the visual
22 training programme increased visual skills of these elite hockey players. More interestingly,
23 goalkeepers outperformed all other groups at the post-test (significantly better than
24 defenders). As there were no differences among positions at the pre-test, goalkeepers
25 responded better to the visual training programme than any of the outfield players. A look at

1 scores on the individual tasks shows that goalkeepers significantly outperformed all other
2 positions on Horizontal Saccades, Vertical Saccades, and Focus Flexibility after the vision
3 training. These three tests involve moving the eyes swiftly from one place to another and then
4 focusing quickly. These visual skills are similar to those goalkeepers employ for much of the
5 hockey match when they are watching the ball being moved around the pitch. Considering all
6 players had the same exposure to hockey-specific training, it is likely that the observed
7 changes are due to the vision-specific training performed.

8 Within the limitations of this study design it is difficult to explain why goalkeepers
9 improved the most on specific tasks. However, in a team sport such as hockey, the position of
10 goalkeeper is relatively separate from those of the rest of the team. The goalkeepers require a
11 vastly different skill set and they spend more time alone (or just with the other goalkeeper on
12 the team) during training and match preparation. This may mean, while the overall training
13 time is exactly the same as that of their field teammates, they get exposed to more high speed
14 tasks in some training time dedicated to goalkeeping skills. Nevertheless, if the differences
15 are due to hockey-related training it does not explain why there were no differences at pre-
16 test as all players had been undergoing similar training regimes for several years. It is
17 possible that the goalkeepers were differently motivated than the outfield players to put more
18 effort into the visual training tasks. Whilst all hockey players require excellent visual skills in
19 order to be able to perform to their optimum, a breakdown in visual skills by a goalkeeper is
20 likely to result in conceding a goal, whereas if an outfield player has a breakdown in visual
21 skills it may just mean then do not select the best possible pass and thus is easier to mask.
22 Further, the three goalkeepers used in this study were competing for just one place on the
23 Olympic team, whereas the eighteen field players were competing for one of fifteen places so
24 there would have been greater levels of direct competition between the goalkeepers and thus
25 their motivation to succeed in every area may have been greater.

1 To conclude, prior to any visual training there were no differences in visual skills
2 across players of different positions within an elite hockey team. However, after a 10-week
3 visual training programme goalkeepers were significantly outperforming outfield players on a
4 number of visual tasks while all players showed benefit. Further studies are needed using
5 randomised cross-over designs for longer periods of time to evaluate the extent of
6 effectiveness of specific visual training programmes on various visual skills in elite
7 populations. It is also important to find ways to quantify on-pitch performance and to monitor
8 this over the course of a visual training programme to assess association between
9 improvement in visual skill and sport-specific performance. These preliminary data suggest
10 the possibility of improving visual skills even in an elite population.

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18

Figure Captions

Figure 1. Screenshots of each of the computer based training tasks and of one practical task.

a) Dynamic Shape Recognition – participants identify the direction that each arrow points as they move across the screen.

b) Rotational Acuity – participants identify the opening in each Landolt C starting with the inner ring. The arrow indicate that the Cs rotated. Alternating rings rotating in opposite directions.

c) Saccadic Eye Movements – participants identified the opening in a Landolt C presented for 250 m/sec at a random screen location.

d) and e) Peripheral Awareness – participants identified which outer shape matched the one in the centre at various eccentricities.

f) Focus Acuity – participants identify the opening in each Landolt C starting with the inner ring. The arrow indicates that the Cs rotated in apparent depth. Alternating rings rotated in opposite directions.

g) Dynamic Visual Acuity – participants track a chain of Landolt Cs moving around the screen and identify the opening in each. h) Rotator Board – participants place a peg in the hole next to each letter of the alphabet in sequence.

Table 1

Raw Scores for All Participants by Task Pre-test and Post-test Mean and Standard Error

Task	Pre-test		Post-test		Percentage improvement
	Mean	SE	Mean	SE	
Dynamic Shape Recognition	56.6	2.1	70.9	1.8	25.3
Rotation Acuity	30.2	1.9	42.6	1.6	41.1
Saccadic Eye Movements	48.1	2.4	64.3	2.9	33.7
Peripheral Awareness	37.0	2.8	44.1	3.1	19.2
Focus Acuity	35.4	2.1	54.2	2.7	53.1
Dynamic Visual Acuity	73.6	3.0	87.2	1.4	18.5
Horizontal Saccades	64.6	2.1	86.2	2.8	33.4
Vertical Saccades	60.7	2.0	82.3	2.5	35.6
Focus Flexibility	71.7	2.0	87.2	3.2	21.6
Rotator Board	14.0	0.8	20.0	0.9	42.9
Recognition Task	6.7	0.3	8.3	0.3	23.9

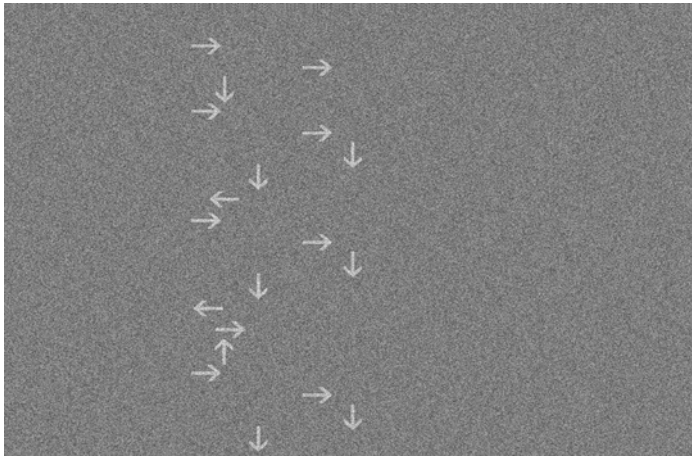
1 **Table 2**
 2 *Raw Scores by Task and Playing Position at Pre-test and Post-test Mean and Standard Error*

Test	Pre-test								Post-test								Percentage improvement			
	GK		Defender		Midfield		Forward		GK		Defender		Midfield		Forward		GK	Defender	Midfield	Forward
	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	M	SE	%	%	%	%
Dynamic Shape Recognition	57.0	2.4	53.6	5.0	56.6	4.2	59.3	4.1	75.5	2.0	66.4	3.2	72.3	2.9	71.5	4.6	32.5	23.9	27.7	20.6
Rotation Acuity	40.7	8.8	28.3	3.6	29.5	3.0	27.6	1.7	48.3	2.0	40.9	1.3	43.3	2.6	40.8	4.7	18.7	44.5	46.8	47.8
Saccadic Eye Movements	51.5	10.0	42.7	3.5	54.2	3.8	48.6	4.2	76.5	4.8	61.5	5.2	65.3	4.6	60.1	6.7	48.5	44.0	20.5	23.7
Peripheral Awareness	38.2	8.7	32.5	4.9	38.1	4.3	34.2	6.0	62.2	3.5	49.4	6.4	55.5	3.3	53.8	7.2	62.8	52.0	45.7	57.3
Focus Acuity	42.0	3.9	31.7	5.6	41.7	2.5	35.0	4.4	53.3	2.0	36.3	3.1	48.7	3.6	42.7	7.9	26.9	14.5	16.8	22.0
Dynamic Visual Acuity	78.0	7.5	70.1	6.7	73.9	4.3	74.4	7.0	94.2	2.6	84.2	1.9	89.7	1.0	84.2	3.3	20.8	20.1	21.4	13.2
Horizontal Saccades	62.0	10.8	63.3	3.8	67.2	4.4	64.5	2.4	108.3	6.6	79.3	4.2	86.5	4.2	81.8	1.2	74.8	25.3	28.7	26.8
Vertical Saccades	56.7	8.3	59.0	2.5	65.3	3.3	58.3	4.3	104.7	4.8	73.7	1.8	82.2	3.4	80.0	2.3	84.7	24.9	25.9	37.2
Focus Flexibility	77.3	6.0	66.5	3.5	77.0	2.1	66.7	3.9	113.3	9.7	80.5	4.0	83.2	3.5	85.0	4.3	46.6	21.1	8.1	27.4
Rotator Board	15.3	1.9	13.3	1.5	14.0	1.5	14.2	1.5	18.7	3.2	18.8	1.1	22.0	1.6	19.7	2.2	22.2	41.4	57.1	38.7
Recognition Task	5.7	0.9	6.8	0.3	6.5	0.7	7.3	0.3	9.7	0.3	7.3	0.7	8.0	0.5	8.8	0.6	70.2	7.4	23.1	20.5

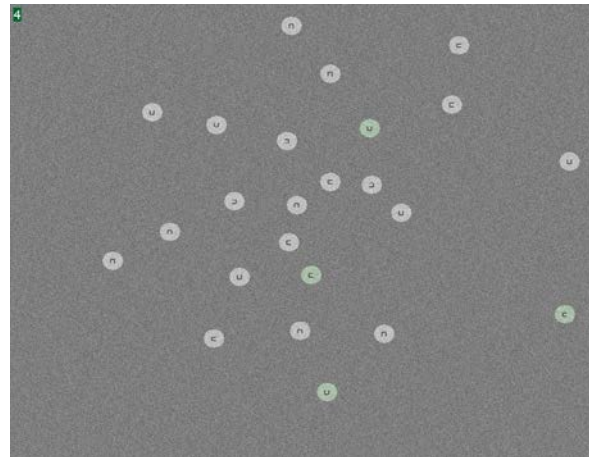
1 **Figure 1**

2

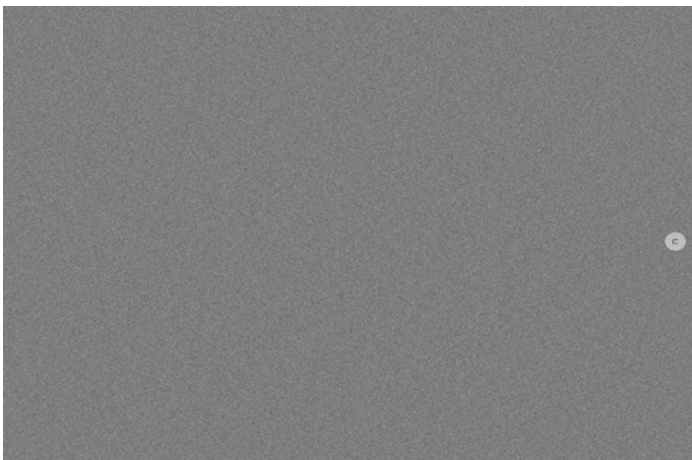
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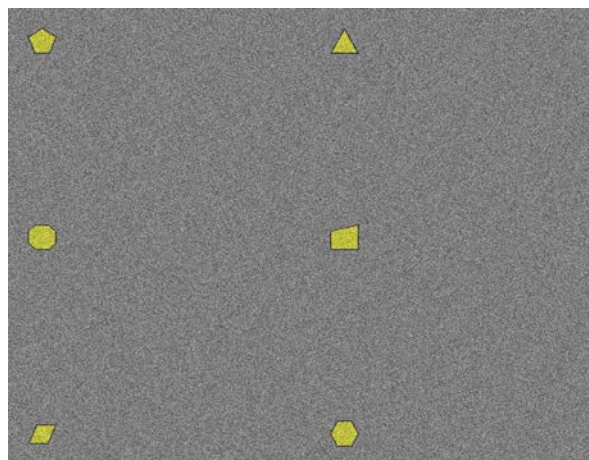
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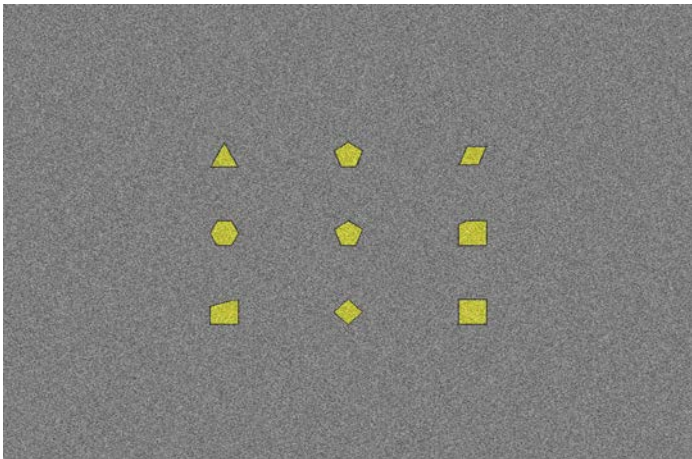
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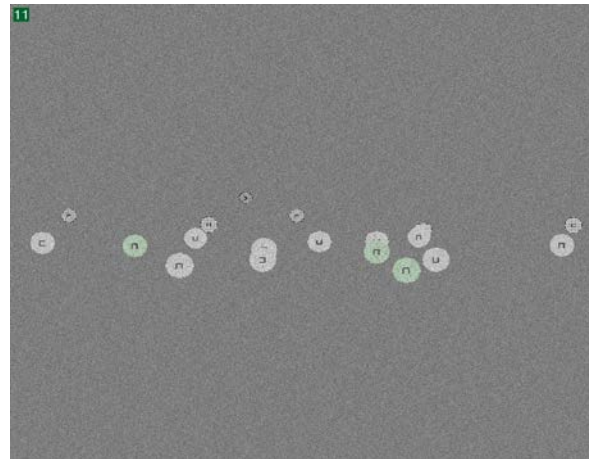
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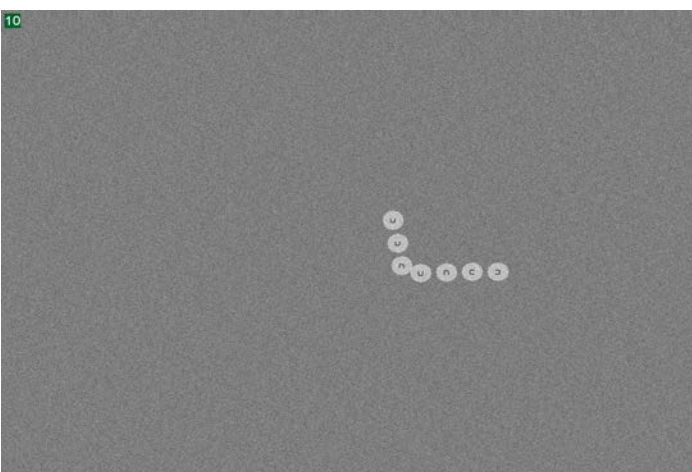
e



f



g



h

