# Temporal action segmentation in rooks (Corvus frugilegus) – a three second window or the fast lane?

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## Abstract

*A three second window has long been suggested by Pöppel (2009) and others, to guide the human perception. More recently, a three second constant has been suggested in overt human behaviour (Schleidt, 1988) as well as in mammalian species in general (Gerstner & Goldberg, 1994). It is however unclear whether this temporal window exists in other vertebrate species. This study examines the existence of a temporal constant for overt behaviours in rooks (Corvus frugilegus), and discuss the methods for studying temporal constraints in overt behaviours. Results point to a shorter temporal window in rooks compared to mammals. However, the mechanisms behind this temporal constraint in behaviour are still unknown and should be considered as an ongoing investigation*

## 1. Introduction

### 1.1 Temporal Action segmentation

The notion of temporal segmentation in human perception is not new, for half a century researchers have found evidence of a time interval where human perception appears to operate optimally (Pöppel, 1994; Pöppel, 1997). However, in recent years this temporal constraint on our perception has also been observed in our actions (Schleidt, 1988; Schleidt & Feldhütter, 1989).

The behaviours performed in everyday life can be viewed from different perspectives, at different levels of actions. In order for a behaviour to be studied and analyzed, a goal i.e. a distinct purpose, is required or each separate action is just a random event. A sequence of actions has to be relatively close in time for it to be perceived as a directed behaviour making the time aspect important. The time aspect of different behaviours is of special interest as studies have shown that behaviours are performed within a specific window of time that seem to be constant for a number of mammals (Gerstner & Goldberg, 1994). Although researchers have found indications of a perceptual optimization regarding duration in time there are many questions left to answer.

When studying behaviour and more specifically *action segmentation,* the behaviour is considered to be divided into temporal units within a certain time range (Pöppel, 2009; Schleidt & Kien, 1996). On the highest level, a behaviour can consist of a single unit, e.g. "drinking". However, when examining the behaviour in detail, a number of small actions are revealed. The hand reaches for the cup, grabs it, brings the cup to the mouth, drinks, and then puts it back on the table. What was described as a single action on the highest level now consists of six single movements. However when regarding the small movements, there is still a common goal, i.e. to drink, which is in line with the definition used by Schleidt & Kien (1997). The different movements are together considered as a single *action unit.* There are however differences in the segmentation between repetitive or non-repetitive behaviours. Studies have shown that actions performed in non-repetitive behaviours generally have shorter durations than those performed repetitively. That is to say, although repetitive behaviours cover a long time span, each movement in the repetitive behaviour is short. This could be due to the repetitive nature and may point to different complexity in the different types of behaviour (Schleidt & Kien,. 1997).

### 1.2 Time perception

Time perception is most likely an important aspect in the everyday life in a range of animals, including humans, but has for a long time been an understudied area. However, recent years have seen a reawakened interest of this field.

While our spatial presence in the physical world is quite substantial and easy to interpret due to our senses (such as auditory, visual and tactile systems) our temporal position is a quite different matter. It stands to reason that time perception is guided by internal cues. Since no single neural unit have yet been identified, there is an ongoing debate on where our sense of time is actually located (Wittmann, 2009). In fact there are a number of questions to be resolved; where our actual sense of time is located, if it is constructed of a single neural unit or it is distributed over a large area in the brain, is time perception task dependent, are there different systems depending on short or long durations? But as Wittman (2009, p.1963) points out "*Too many contradictory theories exist—in psychology and neuroscience alike—that aim at explaining how we judge duration*". The quest for a sensible explanation for the experience of time is ongoing. However this paper will focus on the *three second window,* and the consequences of a limited window of experienced time.

Ernst Pöppel, at Ludwig Maximillan Munich University, has spent many years exploring time perception in humans. He suggests five basic experiences which are part of human time perception: simultaneity, non-simultaneity (asynchrony), succession, duration and the subjective present (Pöppel, 1989). Furthermore, Pöppel (1996) refuse the concept of continuity in subjective time. He claims that humans perceive a few seconds at a time (Schleidt & Kien, 1997). Pöppel (1989) points to various observations and experimen-

tal evidence for these temporal phenomenons, some of the evidence is introduced below.

Pöppel (1989), states that our time perception has different thresholds depending on the experience, and the stimuli. To be able to determine which of two stimuli was activated first, the stimulus has to be separated by at least 20-40 ms (Wittmann, 1999), what Pöppel (1989) refers to as part of the experience *succession*.

Pöppel (1989) means that the experience of *duration* is subjected to the memory, and that the experience is affected by the mental activity of the specific moment. That is to say, the event can be experienced as long or short, dependent on the amount of activity at that moment. In addition, Pöppel (2004) concludes that, in order for humans to perceive an event as a duration, a stimuli has to be at least 40 ms long or we merely perceive it as a "time point".

Furthermore, Pöppel (2009) means that an understanding of human time perception, is vital for the understanding of some of the interactions in human neurology, such as the sensory systems. For instance, Pöppel mentions a *synchrony*, i.e. the signal transduction in humans when perceiving a stimulus. That is, the time it takes for a stimulus to reach the sensory organ as well as being transformed in to energy the human brain can detect. Two different auditory stimuli are perceived as a single unit if they are close to each other in time, this threshold is about 2-3 ms. Following Pöppel's line of thought, it is almost out of necessity that a temporal aspect is present in our brain, as many inputs are separated in time, .e.g. the visual system is separated from the auditory system (Pöppel, 2009).

Pöppel (1989; 1997; 2004) uses the evidence as an indication of a "brain clock", controlled by rhythmic activity generated by neurons, in different parts of brain. This rhythmic activity created by neurons, is referred to as *neural oscillations*. Pöppel (2004) proposes that one period of an oscillation, triggered by a stimulus, act as an integration unit between differences in temporal and spatial information. Furthermore, Wittmann (1999) suggests that perception and action share the timing mechanisms in the human brain and are thus linked together. Additionally, it has been suggested by Schwender et al., (1994) that spatially distant clusters of neurons can communicate/synchronize activity through neural oscillations. Neurons in the cortex discharge the oscillations when a stimulus is presented, and simultaneously activates clusters of oscillatory activity at spatially different locations.

Llinás & Ribary (1993) have recorded oscillations in the vicinity of 40 Hz, in wakefulness as well as in dreaming. This wavelength appears to be present in many neural systems, and is believed to co-activate different regions in the brain. This provides the temporal binding when activated by a stimulus, creating a single cognitive experience. Llinás & Ribary (1993) suggest that oscillations in the vicinity of 40 Hz, are essential for human cognitive mechanisms. Additionally, Schwender at al., (1994) mean that the neural oscillations could be vital part of a basic neural program which controls sensory information processing in humans

Many areas of the brain have been identified as being involved when perceiving time: the basal ganglia, the cerebellum and the frontal cortices have all been mentioned in connection to time experience. However, none of them has been proven to control the precise neural mechanisms responsible for the human sense of time (Wittmann, 2009), e.g. the difference of stimuli only 2-3 ms apart.

*1.3 The three-second window in perception*
According to Pöppel (1989) there is another, integrating mechanism, affecting human perception. This mechanism operates on a lower frequency than the neural oscillations, and binds successive events for up to 3 seconds (Pöppel, 1997). Like the clusters of neural oscillations, thanks to this mechanism of integration we have a single cognitive experience even within longer intervals. Pöppel (1989) called this phenomenon *"the 3-second window of temporal integration"*, which in short is our sense of "now". This integrating mechanism can be demonstrated for the phenomenon Pöppel (1989) refers to, as the *subjective present*. When discussing human perception Pöppel's suggestion of a subjective present is of importance, as he claims that time is not perceived on a continuous scale but rather piece by piece, a few seconds at a time (Schleidt & Kien, 1997). Pöppel (1997) means that every 2-3 seconds, mechanisms in the sensory systems of the brain "opens up" for new information, giving us opportunity for further input. It should be mentioned that Pöppel (2004) points out, that the three-second window does *not* have the characteristics of a physical constant. Furthermore he means that subjective variance is to be expected for this temporal integration window.

Wittmann's (2009) remark about the lack of proof of a controlling neural mechanism is also true for the three second window, which in perception seem to be well established. However, the functional structures behind it have not yet been fully revealed. The three second constant is presumably present in many of the systems in human perception, as well as in our actions. Some of our senses seem to depend on this subjective present in order to get a better view of the world (Pöppel, 2009). However, he is not alone in this theory and others have based experiments on his findings and found similar results (e.g. Mates et al., 1994; Schleidt, 1988; Schleidt & Kien, 1997; Vollrath et al., 1992).

Even if the concept of the three second window is quite new, the benefits of a temporal constant in itself seem to have shaped our cultural world for hundreds of years and continue to do so even today. The musical themes in pieces of masters such as Mozart, Beethoven and Hayden all have a range of a few seconds. For more recent examples we only have to turn to commercials on television where studies have found that the directors often use structures of 2-3 seconds for each scene. The use of these temporal intervals most likely reflects the preferences of the audience, and was used by the composers and directors based on experiences of which musical pieces, or commercials, were well received (Schleidt & Kien, 1997).

Vollrath et al., (1992) showed that human speech is temporally segmented. When examining what they called "sin-

gular speech units", i.e. sentences, they found a common temporal segment of 2.6 s. That is to say that in average a sentence is somewhere around three seconds long, well in compliance with the predictions of Pöppel's three-second window.

Further evidence comes from studies made on ambiguous stimuli. When perceiving the optical illusion of the Necker cube, an image which can be viewed in two different perspectives (figure 1.), it is impossible to sustain a continuous image of either perspective, given that both possible perspectives have been detected. When observing the cube in one perspective, a reversal to the other perspective is automatic and inevitable. Human perception shifts between the two different perspectives and the reverse rate for the Necker cube, as well as other ambiguous figures, is consistently close to three seconds (Pöppel, 1997).

However it is not only visually ambiguous stimuli that affect perception in this manner. Ambiguous auditory stimuli show similar effects when shifting between different perspectives. When perceiving sounds of similar syllables, such as "ku-ba-ku" (/bacu/ and /cuba/), the interpretation shifts every 3 seconds (Radilova et al., 1990). Pöppel (1994; 1997) means that the brain seems to "update" every three second, where the sensory system is more receptive and can obtain new information

In 1994, Mates et al. demonstrated that the human sense of rhythm is affected by the length between beats. Participants were to tap their finger in synchronisation with an auditory stimulus. Considering the limitations of human motoric action, the participants in the study had to anticipate the next onset of the beat. The majority of participants managed this for stimuli up to stimuli-durations of just below three seconds. In the interval between two and three seconds, the results show that there is a shift in strategy. Instead of anticipating the next beat the participants begin to react to the beat. This could have its explanation in neural constraints regarding time mechanisms in humans where the integration of temporal events reaches its limit. This also explains the individual differences, as some subjects developed somewhat different strategies (Mates et al., 1994).

Further evidence of the three-second window comes from the finding, that humans tend to reproduce very short intervals longer and long intervals shorter (Pöppel, 2004). Pöppel (2009) suggest that between the very long and very short intervals, an interval that is correctly reproduced should exist, which is referred to as the indifference point. Furthermore, Pöppel (2009) propose that this point occurs approximately at three seconds, when intervals are chosen between one and several seconds. The study concluded that a two, to three second integration is common in all temporal aspects of human perception, and that the neural machinery is guided by this temporal window creating the humans sense of "nowness" (Pöppel, 2009).

### 1.4 The three-second window in action
The theory of a three second window in perception has a fairly substantial ground, and is backed up by a number of studies. A somewhat more recent area is that of a three sec-
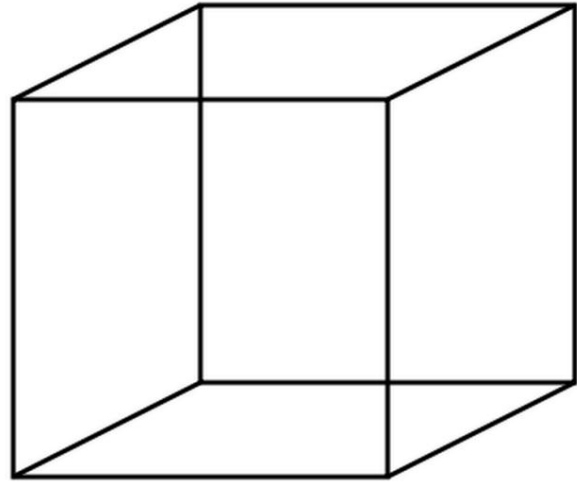


Figure 1. The ambiguously drawn Necker cube, creates an optical illusion with two possible perspectives. If both perspectives are detected, a spontaneous shift between the two perspectives occurs every 2-3 second. (Pöppel, 1997)

ond window in action. That is to say that human, and possibly other mammals, not only perceive actions in a three second interval they also perform actions based on this interval.

Schleidt (1988) examined every-day actions of four different cultures. The behaviours were analyzed from video films, collected from different parts of the world. The study focused on behaviours where repetitions were common (e.g. waving, clapping, nodding) as they are structurally easy to measure and to time accurately. They also often have a clear goal and can be perceived as voluntary acts (Schleidt, 1988). Rituals and games were excluded as they follow other rules than a merely goal directed action. The results reveal that a significant amount of behaviours in all cultures have a mean value between 2-3 seconds. Furthermore, no matter whether the person was alone or engaging in a social interaction, the number would still fall in the same interval (Schleidt, 1988).

There are however repetitive behaviours that are stereotypical in nature which can go on for up to 55 seconds. The structure of stereotypical behaviours are short actions, often no longer than one second, repeated over and over again. These stereotypical behaviours are suspected to have a soothing effect and calms down the system (Schleidt, 1988), e.g. stereotypic behaviours are common in zoo animals, where stress and frustration are believed to be influencing factors (Jensen, 2006, chap. 10.).

In a follow up study by Schleidt & Feldhütter (1989), non-rhythmical behaviours were further investigated. The material was the same as in Schleidt (1988), but only data from two of the four cultures were included. The authors focused on working activities and movements with hand body contact. The median of the behaviours was 2, 9 s. The results show that these behaviours also fall in the range of the three second window. Schleidt & Feldhütter (1989, p.128), postulates that *"...rhythmically repeated movement patterns of short term behaviour are a basal component of human movement and help structure ongoing behaviour..."*

Schleidt (1988) concludes that only about 15 % of the behaviours examined did *not* follow the three second span. Hence the three second window was concluded to not only exist in human perception but also in overt every day behaviours.

A more recent study was conducted in 2010, when Nagy examined the occurrence of the three second constant in human embraces. Data collected during the 2008 Summer Olympics were analyzed, and the duration of spontaneous embraces between competitors, as well as trainers, was calculated. The duration for an embrace was found to fall within the three second window, regardless of the combination of the gender or familiarity between the two subjects. Nagy (2010) concludes that the three second window appears to be a building block in not only our perception but also in our synchronised intersubjective experiences.

Given that the three second window seems to be present not only in human perception (Pöppel, 1989; Mates et al., 1994; Pöppel, 2004) and speech (Vollrath et al., 1992) but also in our actions (Schleidt, 1988; Schleidt & Feldhütter, 1989), it is almost to be expected that our closest relatives share this constant.

Chimpanzee (*Pan troglodytes*) hand movements were studied, in order to compare with similar studies of humans, and to examine whether the three second rule exist in non-human primates as well (Kien et al., 1991). For accurate comparison the hand movements were divided into non-repetitive and repetitive (action units with two or more repetitions). In the non-repetitive behaviours the distribution of the chimpanzees' durations was similar to that of humans. However the median duration was significantly shorter in chimpanzees relative to humans, 0.9 s for chimpanzees whereas the median for humans was 2.0 s (Kien et al., 1991). In the repetitive behaviours there is still a significant difference between chimpanzees and humans, although not as big as in the non-repetitive category. Here the chimpanzees had a median of 2.4 s whereas the humans had a median of 3.0 s.



*Figure 2. The rook (Corvus frugilegus) is a rather large bird, making them relatively easier to observe compared to smaller species.*

The authors suggest that the results point to temporal constraints in chimpanzees' behaviours, similar to those present in humans. When repeating an action, i.e. repetitive behaviour, the similarities are clear as in both species there are indications of planning or advance sequencing to fit both actions in to the temporal window. The difference in time is believed to has its origin in human capability to better time the muscle contraction required in planning a precise motoric action (i.e. hand movement) (Kien et al., 1991).

One step further was taken by Gerstner & Goldberg (1994), who widened the concept of temporal segmentation in overt behaviour to include not just primates, but mammals in general. Using similar methods as Schleidt (1988), the authors studied the behaviour of six different mammalian species. However, in order to be able to include *all* movements in the study, rather than focusing primarily on goal-directed actions, Gerstner & Goldberg (1994) created an ethogram based on visibly motoric behaviours. The animals were recorded on video on different occasions during a period of one and a half year, and then analyzed based on the ethogram. Ranging in size from the largest subspecies of giraffe *(Giraffa camelopardalis tippelskirchi)* to the red panda (*Ailurus fulgens),* the participating animals represented a wide range of physiological attributes as well as differences in the social environment. The actual environment was also different for the animals as the weather at the locations differed and the temperature ranged from -2°C to 46°C.

After analyzing all the collected material, the results show that the three second window indeed seems to be present in other groups besides the primates. The mean event duration for each species were between 1.6 s and 4.8 s, however this include the inactive states where the animals ruminate and/or rest. They conclude that the study provides strong evidence for a 3 s. constant in overt behaviour in other mammalian species as well, and that it is not unique to humans (Gerstner & Goldberg, 1994).

### 1.5 Aim of the study

Although Gerstner & Goldberg (1994) have found support of the three second window in six different mammalian species, there is still the question of whether this constant is unique to mammals. The aim of this study is to determine whether the three second window exist in the rook (*Corvus frugilegus).*

## 2. Rooks (*Corvus frugilegus*)

### 2.1 Why Rooks?

As the three second window could be considered to exist in mammals (Gerstner & Goldberg, 1994) an essential question is whether this interval is present in other groups of animals. Birds are an interesting group to study in this context as they are evolutionary distant to mammals (Solomon et al. 2005) and could serve as a building block in the pursuit of the physiological and neurological basis of the three second constant in action. As rooks are quite large birds (figure 2.) it is relatively easier to record and analyze their movements compared to smaller birds.

## 2.2 Neural Structures and Cognition

Birds and mammals went their separate ways on the evolutionary road hundreds of millions of years ago. The closest relatives to the bird family are believed to be dinosaurs (Solomon et al. 2005). Birds and mammals have similarities in the structure of the brain, there are however differences. As an example, previously it was believed that all of the birds' pallium was part of the basal ganglia, as the bird pallium differed from the human. However, in the avian striatal structure, an internal structure in the brain, only a small portion is homologous to the mammalian basal ganglia (Shimizu, 2009). Even though birds do not have exactly same neural structure as mammals they have evolved to cope with equivalent cognitive challenges.

The view of birds' brain has changed over the years, and modern day insights support the assumption of a higher developed brain structure (Shimizu, 2009). Even though there are structural differences, they have a high level fore-brain structure, which has been regarded as necessary for an animal to display behaviours considered to be evidence of advanced cognitive skills (Shimizu, 2009). That all vertebrates share a basic design of organization of the brain, which includes both a pallium and basal ganglia, are supported by data updated in recent years (Shimizu, 2009). In the light of the new, and evolutionary more accurate, structures many of the complex behaviours in birds could be understood. For instance, they are believed to have the ability to store and manipulate visual information in their memory, similar to our working memory (Orosz, 2005).

So how and why did corvids develop their cognitive skills? Some species of animals appear to have developed what can be described as higher levels of cognitive skills than others. A high level of cognition could for example be defined as the ability to use tools, to excel in memory tasks or show insight in the knowledge of others (theory of mind). Why, and how, some animals have developed a higher level of cognitive abilities in comparison to other species is still under debate.

The use of tools has long been thought of as an indicator of high level of cognitive skills. Although some corvid species make use of tools in the wild, New Caledonian Crows (*Corvus moneduloides*) are expert tool users (Milius, 2005), rooks are not one of them. However, experiments have shown that rooks in fact are quite capable and have sufficient cognitive skills of using tools when required (Reid, 1982; Tebbich et al., 2007; Bird & Emery, 2009).

## 2.3. Perception

### 2.3.1. Vision

Birds gather information about their surroundings mainly through visual information and most birds have large eyes relative to their body size (Fernández-Juricic et al., 2004). The visual impressions of an object is very important to birds, revealed partially by the fact that their optical nerve has a very large diameter. Humans have only 40 % of the number of retinal axons per optic nerve, compared to pigeons or chickens (Orosz, 2005). They also have the ability to see light in the near ultraviolet spectrum allowing them to determine further information from visual stimuli (Orosz, 2005). A study from 1994, by Finger & Burhardt, shows that the plumage of some bird species could have evolved to produce maximum stimulation in their colour vision, including the ultraviolet spectrum (Finger & Burhardt, 1994).

Most birds have a wide visual field allowing them to be aware of predators while searching for food (Fernández-Juricic et al., 2004; Dawkins, 2001). Despite a large visual field they can't see everything and they use head movements to scan their entire surroundings. Birds appear to use head movement as saccades and the movement of the eye seem so to function as a way to accommodate the head movements (Land, 1999; Dawkins, 2001).

When comparing bird vision with humans, there are naturally some differences. One is the speed at which birds perceive the world. Due to their use of flight, birds have to be able to detect motion and object at high speeds, a measurement of the ability to perceive high speed objects, is called the flicker-fusion frequency (FFF). This measurement is largely dependent on the density of photoreceptor, and birds have plenty of them compared to humans, giving them a superior ability of perceiving motion. While the FFF of the human eye is 50 to 60 Hz, the bird eye has a mean FFF-value of 100 Hz and can thus perceive motions at almost twice the speed of humans. This means that any motion over 60 Hz is perceived as a blur by humans while a bird sees it as a series of separate movements. A common example is that of a florescent light bulb oscillating at 60 Hz, which humans see as a steady flow of light, a bird would perceive as a constant flickering (Jones et al., 2007).

### 2.3.2. Hearing

Although the visual world is their primary source of information, the auditory sensory system of birds is also well developed, though not as developed as in mammals (Orosz, 2005, p 14). Comparable to the auditory system of humans, auditory stimuli has to be separated by an interval of 2-10 ms, depending on the species, for the stimuli to be perceived as two separate stimuli. In addition, birds appear to have a closed loop, similar to connections between the basal ganglia, the thalamus and the cortex in humans. This loop is important for motor control and cognitive functions. This indicates that birds seem to meet the criteria for a vocal learning similar to that of humans (Orosz, 2005).

### 2.3.3. Time Perception

As with humans, little is known about the specifics in time perception in non-human animals presumably even less so, since it is hard to set up experiments to measure perception compared to humans who can explain what they perceive. Overall the only consensus is the existence of the circadian (24h) rhythm which seem to be a common ground for all vertebrates (Paul & Schwartz, 2010) and possible all organisms. The most commonly acknowledged time perception in birds are those of the circannual (yearly) and circadian (24h) rhythms guiding their behaviours (Campbell, 1996), of which a well known example is the migration of some birds which

is largely guided by the circannual system, occurring on a yearly basis, spring and autumn. A study from 1996 by Gwinner, suggests that the combination of the circadian and the circannual rhythm together give birds their sense of time. The physiological factors behind the rhythms in birds are yet obscure but depend on hormonal variations (Gwinner, 1996). However in a study from 1999, Clayton & Dickinson showed that the scrub jay *(Aphelocoma coerulescens)*, which is also a member of the family corvidae, possess the ability to match food items to a specific moment time (as well as a location), as they consistently chose the hiding place where the food was fresh. Thus they have the ability to recall the spatial position, for a particular event (Clayton, 2004); this indicates a more precise time perception, compared to a 24h limitation.

## 2.4. Social life
Rooks form colonies, large social groups, and they roost, forage and nest together. They form social and mating couples for life, and often return to the same place to roost and nest year after year. Group life is preferred by many species of birds as it provides the safety from predators as well as information about food sources (Seed et al., 2007). Rooks show signs of consolidation after conflicts with individuals other than their partner, a social occurrence also found in primates (Seed et al., 2007). They have also been found to understand the value of cooperation in a task where the success is dependent on the cooperation of two individuals (Seed et al., 2008). As they live in complex social environments, rooks have a wide spectrum of vocal communication (Röskaft & Espmark, 1982) and like many other birds, a large number of visual cues, i.e. body postures. (Fernández-Juricic et al., 2004).

## 2.5. Hypothesis
Birds perceive the world faster and must often react to it in the same speed. As their senses have evolved to a higher velocity, their neural mechanisms should have adapted, to cope with the flow of information giving them the advantage of a "fast lane". As perception and neural limitations seem to be to the ruling force in the three second window in mammalian species, the hypothesis in this study is that that the temporal segmentation in rooks has a shorter window. However this hypothesis rests on a foundation of the assumption that perception and/or neurology really are the controlling factors.

Another possibility is that physiology is a factor in the temporal action segmentation, meaning that a smaller animal moves faster. Thus, the temporal window would still be shorter in rooks than in humans and other studied mammals. This is based on indications from Gerstner & Goldberg (1994).

# 3. Materials and Methods

## 3.1 The Animals and housing conditions
The animals in this study were kept in a large aviary (140 m$^2$) and 5.10 m high. The group consisted of six birds of approximately the same age (five 2-year-olds and one 1-year-old). The birds had access to the entire complex and could choose to be outside or inside. The aviary was situated next to a barn with one door always open where the birds could rest at night and seek shelter during the day.

## 3.2 The Study
The birds were filmed during different periods of the day. Rooks are highly neophobic i.e. they are known to show fear towards new things (Seed et al., 2008) and since no tripod could be used due to the birds fear, the camera had to be controlled by hand. However on one occasion, when food was left on the ground, the camera was left on a table already present in the aviary. The rooks were careful and kept a safe distance from the camera, resulting in some difficulties to make detailed observations.

Initially, about 30 % of the material was chosen at random and then analysed. Based on the observations a preliminary ethogram was created describing all observed behaviours. The behaviours described in the preliminary ethogram, were used as guidelines and further discussed with ethologists in order to be as accurate and easily detectable as possible. The behaviours included in the analysis had to have a clear onset and offset and clearly defined goal. Behaviours without a discernable goal were considered to be states, or passive behaviours. In the end, the ethogram (appendix 1.) contained 24 different defined behaviours, including the passive behaviours. There were also three other categories where the animal was partially or totally out of sight (OOS), and one category called "other", which were behaviours that couldn't be identified.

Continuous focal observation was used, i.e. one bird was observed for the whole duration of a clip. Only when behaviour was observed without any visual obstruction could it be recorded, i.e. if a bird was hidden behind a branch and the behaviour could be inferred on the basis of the situation it still was not recorded.

In total, 106 minutes of material was recorded. However, a technical mistake with the annotations in one of the clips rendered the data useless, resulting in 95 minutes of analyzed material. The total amount of time observed was 128 minutes and 17 seconds. The difference in time in the filmed material and the observed material is due to that some films include more than one bird.

## 3.2.1 Equipment
When filming the birds, a camcorder (Sony HXR-NX5E) was used. The films were converted to a suitable format for the ELAN software, and then analyzed.
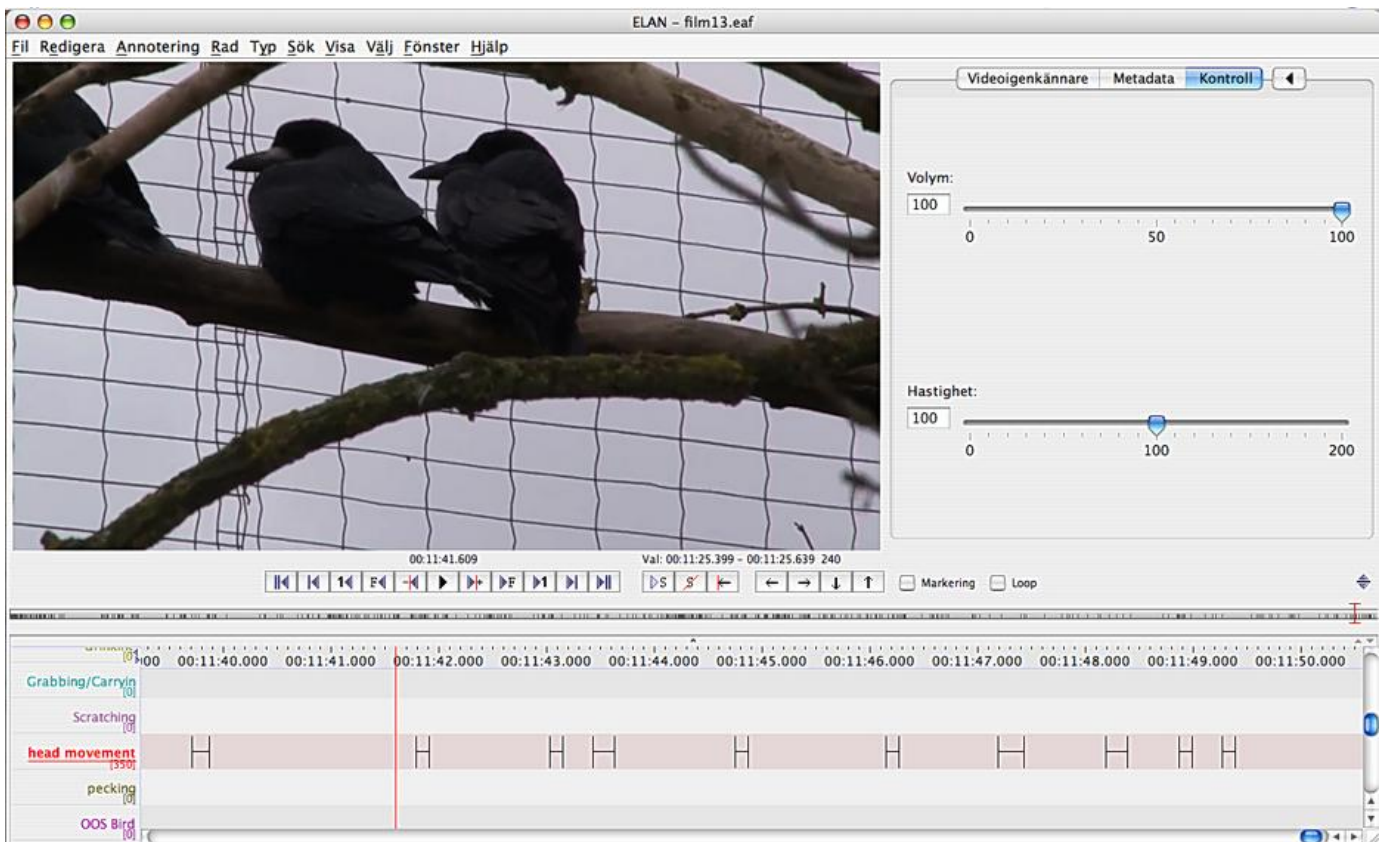
*Figure 3: A screenshot from the annotation software ELAN. Each row represents a behaviour, the black vertical lines indicate start and stop for the behaviour. The red line indicates the current time position in the film. A common sight in the films; two rooks sitting close to each other in an elevated position on a branch.*

### 3.2.2 Analysis

The films were analyzed in the annotation software ELAN (figure 3). Based on the onset and offset, the length (duration) of each behaviour was recorded. The films were all analyzed frame-by-frame, and a behaviour had to be at least 40 ms in order to be detected, as this was the duration of one frame.

Only behaviours with a clearly defined goal were accounted for. These behaviours were considered to be states, or passive behaviours, and cannot be perceived as goal directed actions

### 3.3 Interreliability

An interrater test was used to calculate the reliability of the methods used in the study. A person (investigator) who was familiar with the study was enlisted to review a percentage of the films. However it should be pointed out that even though the study was familiar to the enlisted investigator, the tools used to analyze the videos were not. The material reviewed was randomly selected, unfortunately due to technical problems leading to some lack of time, only 13,5 % (4 min 46 s.) of the total amount of material (128 min 17 s) was reviewed.

The result of the performed analyse by the enlisted person, was compared to the result of the same material analysed by the author. The test score was 70 % (0,695) for the number of matching behaviours giving a kappa coefficient value (κ) of 0,5. The percent of agreement is just within the acceptable range, which is usually said to have a lower limit of 70% (Bordens and Abbot, 2001). The agreement in timing of start and stop for a behaviour were calculated, using all 341 observations made in the comparison. The average difference for the start time was 0,078 s and 0,162 s for the stop time, i.e. 2 respective 4 frames difference.

### 4. Results

In total, 5739 observations were recorded, however 4905 of these were of the behaviour "head movements". The behaviours where the bird was out of sight was excluded from the analysis, this meant that 5478 observation remained. The mean duration and standard deviation was calculated giving a result of *0,68 s ± 11,62 s.* The high value of the standard deviation is due to the fact that the category "sit" is included. In some of the films the bird sat the entire time (e.g. 11 min 54 s.)

To get a more accurate calculation some of the behaviours had to be excluded from the data set. The "passive" behaviour (sit), and behaviours without a discernable goal (walk, run, fly), were removed. The behaviours where the animals were out of sight (OOS) and where the observer was unable to see what was going on (other) was also excluded. This resulted in 5302 observations that still remained. For this data set the mean duration and the standard deviation of behaviours was *0,22 s. ± 0,33 s.* An overview of the result of the different data sets can be seen in table 1.

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However as the behaviour "head movement" was in majority (92%) of the data set, it had a large influence on the mean of the other values. The mean value of head movements was very low (0,19 s). Another calculation was made where "head movement" was excluded. The result for the durations was a mean value of *0,68 s.* with a standard deviation of *1,09 s.* Calculations were also made for each separate behaviour. A box-plot with each behaviour included can be seen in figure 4. Non-goal-driven actions were included, but the behaviour "other" and the passive behaviour "sit" were excluded. In general the behaviours show a low value for the median and fairly low variation. The outlier in the behaviour "foraging", are most likely due to the layer of snow the birds had to remove in order to find the food in some cases, resulting in a repetitive behaviour. The two outliers in the behaviour Grabbing/Carrying is the result of one bird, that on two occasions grabbed some food and carried it away from the rest of the group to eat undisturbed.

## 5. Discussion

### 5.1. The results
The primary results indicate that the durations of rook behaviours are within the three-second window, however in general their behaviours are considerably shorter than human action segmentation.

### 5.1.1. Actions
A temporal constant of three seconds in overt actions, has been suggested by Schleidt (1988) as well as by Gerstner & Goldberg, (1994). In 2010 further verification of the three-second constant was presented by Nagy. When excluding occasions where the bird was out of sight (OOS) the mean duration was 0,68 seconds. Compared to the results in Gerstner & Goldberg (1994) the duration is half the length of the raccoons' (*Procyon lotor lotor*), which had a the shortest duration of the six species studied with a value of 1,62 s ±

*Table 1. An overview of the mean duration and standard deviation in the different data sets.*

| Behaviour excluded from data set | Mean duration and standard deviation. |
|---|---|
| *Out of sight (OOS) (n=5478)* | 0,68 s ± *11,62 s* |
| *OOS, passive and non-goal driven (n = 5302)* | *0,22 s. ± 0,33 s.* |
| *OOS, passive, non-goal driven and head movement (n= 398)* | *0,68 ± 1,09 s.* |

1,65 s. Following the reasoning of Kien et al., (1991) in the study of chimpanzee hand movements, the difference in behaviour duration, could be an indication of a different brain structure and different neural mechanisms in the two species.

When excluding passive behaviours, the behaviours with long durations are the behaviours that can be seen as repetitive, such as "preening", "bathing", "scratching", "foraging" and "billing". That is to say, behaviours which consist of a short action repeated two or more times. However, as the definition for behaviours in the current study often had onsets when the movement began, and offsets when the bird was still again, the repetition pattern was not included as the bird never paused during the movement. It should also be mentioned that the behaviour "wing stretch" was often observed at the same time as the behaviour preening, as the wing was lifted for the bird to be able to clean underneath the
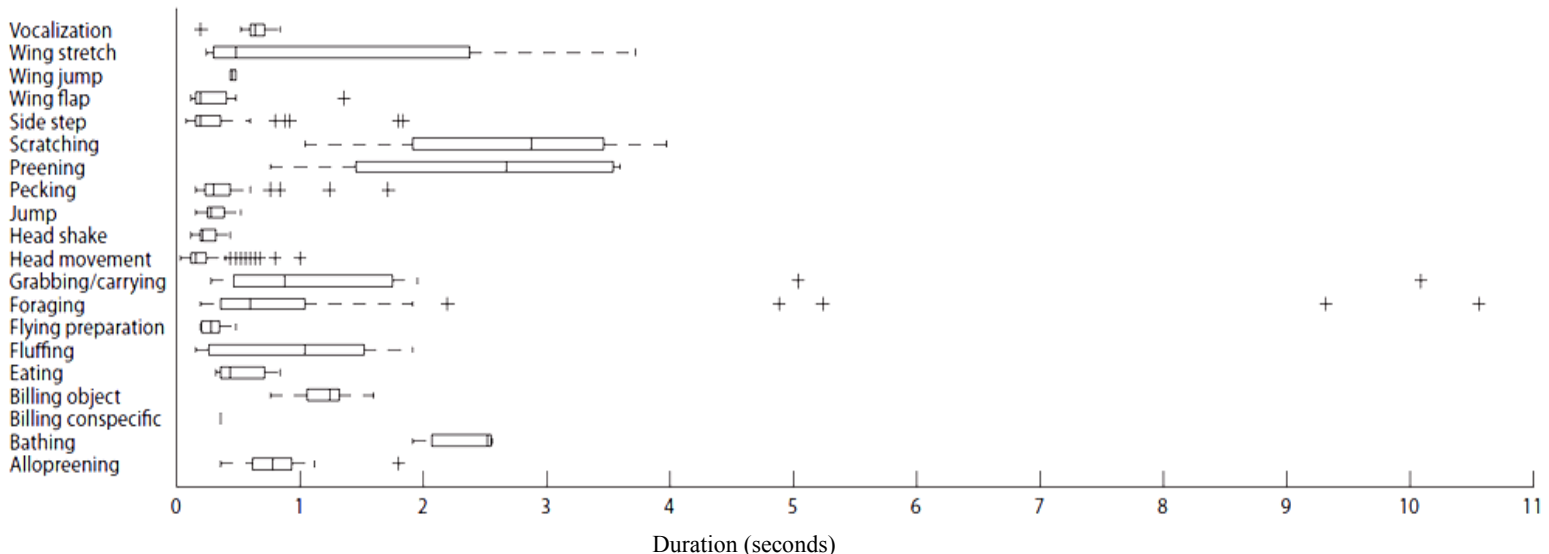


*Figure 4. Box-plot with all the observed behaviours. "Out of sight" and "other" are excluded. The majority of behaviours have a median of less than 2 seconds, and most behaviours also show a fairly low variation of duration.*

wing.

### 5.1.2. Perception

The three-second window in human perception is well established, and rests on a solid foundation of a large number of studies confirming its existence. A behaviour worth some extra attention in this study is "vocalization", unfortunately the sound had poor quality in some of the film clips and could not be analyzed, so the number of observations is rather low. All of the observed vocalizations are however in close succession to another vocalization. Possibly they could be considered as repetitive, or perhaps rooks, like humans, has adapted to the perception of other birds. Further studies of rook vocalization and interaction has to be performed for more accurate results, as the data on vocalization collected in this study only show indications, and is not enough for any statistical analysis.

Another potential perceptual indication, lies between the end point of one head movement, and the start point of the next one. The time between head movements could possibly be used as an indication of when the bird wants new visual information. As a birds' head movement has the same purpose as the saccades of the human eye (Land, 1999; Dawkins, 2001), the head movement represents the change of focus, that is, the search for new information. The mean duration between head movements is 1,4 s. When interpreting this in accordance with Pöppel (1994;1997) one could expect that rooks have a lower upper limit in the temporal window, compared to humans, where the brain is more prone to receive new information. This difference could possibly stem from the highly developed visual perception in birds. If the neural oscillations, suggested by Pöppel (2004) to act as a perceptual common ground in humans, also exist in rooks, their oscillations could be faster, thus producing an overall faster perception, compared to humans. This could possibly also influence the mechanisms featured in the three second window.

### 5.2. Neural structures

Shimizu (2009) argues that the bird's complex behavioural, and cognitive abilities, should be appreciated for what they are and not in competition with human abilities. Our neurological structure may be different, but humans and birds share a high level of cognitive skills as well as the occurrence of complex behaviours. Fact is that bird show more complex behaviours than many mammalian species. Still, Gerstner & Goldberg (1994) claim that the behavioural segmentation exist in mammals, where higher cognitive skills, such as tool use, still has yet to be proven. Furthermore, Gerstner & Goldberg (1994) suggest that the cortex has a fundamental role in behavioural event durations.

Temporal segmentation has been suggested by Kien et al., (1991) to be a pre-existing feature of the pongid brain (the family pongidae; gorilla (*Gorilla gorilla),* orang-utan (*Pongo pygmaeus*) and chimpanzee). Human perception, motor action and language were all supposedly elaborated based on this feature (Gerstner & Goldberg, 1994). Gerstner and Fazio (1995) states that, the perception in humans and other mammals are partitioned into short units, due to a conserved temporal mechanism. However, there is still the question where this prerequisite for temporal segmentation has it origin? Like mammals, birds have developed high level forebrain structure, a feature that is considered to be necessary for complex behaviour (Shimizu, 2009). In fact, some bird species have many complex behaviours, and show sign of highly developed cognitive skills, despite their lack of a cortex.

Given the fact that corvids by all appearances have an episodic memory (Clayton et al., 2003) it would be fair to assume that they also have a sense of time of a more detailed nature than merely circadian rhythm or at least an accurate awareness of duration. Clayton et al., (2003) also argue that the spatial and temporal information is encoded in the memory as an integrated unit. Like Pöppel's (2004) suggestion of neural oscillations in the human brains as a common ground for distributed temporal and spatial information, the same principle could be argued to control the integration of the stored information in the scrub jay. This means that when the bird remembers the place *where* it hid the food, it also automatically retrieve the information of *when* it hid the food.

In this light, whatever difference there is in duration of temporal action segmentation does not appear to necessarily have its origin in neurological structures. However birds' visual superiority could be a contributing factor to the difference in temporal duration. Due to their high velocity vision, their perceptual mechanisms could function at higher speeds, than in humans. That is to say, even if the structures are similar, differences in mechanisms creates the temporal difference.

### 5.3. Physiological structures

An important question is whether there is a difference in all mammalian species, or if some of them have a shorter (or longer) constant than the three seconds believed to guide the mammalian action. One of the smallest animals studied in Gerstner and Goldberg (1994) is the racoon. However there are mammals with significantly smaller body mass (e.g. a large number of different mouse species or bat species).
In Gerstner and Goldberg (1994) there are indications that body size affects the temporal segmentation. The racoon has a mean duration of 1,65 s, whereas the largest, the giraffe, has a mean duration of 4,82 s. Although there is no statistical difference it still shows an indication of a correlation between action segmentation and body size.

If body size has some kind of effect on temporal segmentation, most birds will fall in the "small category". The rook, although a fairly large bird, is small compared to the racoon and this study show a shorter duration, than that of the racoon in Gerstner & Goldberg (1994).

Even if size is not a contributing factor, there are other physiological differences to consider. Another physiological attribute, which could contribute to a limiting temporal constant, is the digestive system. Gerstner & Goldbergs' (1994) study contain some ruminant animals (i.e. giraffe, okapi). The ruminants appear to have relatively high durations and also the red panda, which is rather small, show a relatively

high duration. Pandas diet consist mostly of leaves and bamboo, however, their digestive system cannot digest cellulose. This fact means that pandas have to eat massive amount to obtain energy, leading to the panda's sedentary lifestyle. Maybe the ability to transform food into energy, could have a limiting effect on the temporal constant in action. To further investigate the digestive system's influence, a study on the temporal segmentation of the sloth family (*Bradypus*) should be conducted, as they are notorious for their somnolence lifestyle i.e. their almost sleep-like state.

Gerstner & Goldberg (1994) point to the fact of the differences in sizes and environments in the animals, and their results in duration. However, there are immense variations in physical appearance, as well as environmental adoptions, within the mammalian group. In order for the three-second constant, in overt behaviour, to be firmly established in mammals, I would like to see a larger spread in studied species, from the massive blue whale (*Balaenoptera musculus*) to the tiny Kitti's Hog-nosed Bat (*Craseonycteris thonglongyai*).

### 5.4. Social environment
Schleidt (1988) suggests, that communication and synchronisation between interacting people, could be facilitated by a common time mechanism. As rooks are highly social birds, they could have developed a similar mechanism. However, based on the result in the current study, rooks appear to have a shorter perceptual window compared to humans. Consequently, the overt actions in social interactions would be adapted to a shorter perceptual span. Unfortunately the perceptual features in animals are hard to study, whereas overt behaviours are easier to measure and quantify. In the current study the only social behaviours were "vocalization", "billing with conspecific" and "allopreening". These behaviours where rarely observed, resulting in too small datasets to make any accurate predictions.

### 5.5. Methodological consideration
Given that the three-second window guides human perception, there is the possibility that humans have a bias toward perceiving animals' actions in three second intervals. If this is the case, how can one separate the two (i.e. our perceived action vs. the actual action)? In this study, the films were played frame-by-frame during the analysis. Gerstner[1] means that at those rates, we have de-coupled our perception from the "real time" in which the animals were taped.

There is however the possibility of a bias when creating the ethogram, as it is created in real time and not in slow motion. Is it possible to define onset and offset of behaviour in an unbiased way? Whereas the evidence of the three-second window in perception is substantial and contains tangible data, a three-second constant in overt behaviour lack these solid evidence. The difference in evidence could depend on the difficulties in objectivity when deciding where a

behaviour starts and where it ends. However, the evidence of a temporal window in perception has been studied for a longer period than the constant in action, resulting in a larger amount of evidence. Additionally in most cases these objections are countered with inter-reliability tests. Furthermore, even when the ethogram is controlled by naive investigators, the investigators are still humans, giving the possibility of a bias due to human perception.

### 5.5.1. Interrater test
The reason for a rather low kappa coefficient value was the category "head movements" where the difference was the largest. In most cases where there was a difference, the author found head movements where the investigator did not. However the definition of head movements was quite straight forward (see appendix 1) and not likely to be misinterpreted. When discussing the difference with the enlisted investigator the reported reason was, that it was hard to tell when the wind affected the bird and when the bird moved on its own. Had the investigator had more time the result could possibly improve as the investigator's skill at observation, and perhaps also with the program used for analyzing, increase. Alternatively the investigator could have received some practice, other than merely instructions on how the annotation program (ELAN) worked.

It should also be mentioned that even though there was a difference in number of behaviours found by the investigator and the author, the value of duration was a good match. The result of the calculations on mean duration and standard deviation, when excluding OOS and other (no passive behaviours were recorded), was 0,39 s ± 0,50 s. for the investigator's data set.

### 5.5.2 Neophobia
Even though some precautions were taken, the birds still had some reaction to the camera and the films are somewhat influenced by this fact. The birds were cautious and tended to sit together on high ground. Due to the birds attentiveness the behaviour "head movement" was overrepresented, as they use head movements to survey their surroundings. In combination with their reluctance to leave the branches where they felt safe, the number of other behaviours, when compared with head movements, was rather few. As "head movement" has a very low mean duration, it was excluded to avoid a bias in data set. However, even when the behaviour "head movement" was excluded, the mean duration (*0,68 s.± 1,09 s.*) was still notably below the mean duration compared to studies performed on humans (Schleidt, 1988), and other mammals (Gerstner & Goldberg, 1994).

One problem that arose as a consequence was with the quality of the films, at times a bird was too far away, or the quality not good enough, to readily detect the exact behaviour, it was then noted as "other". The use of "other" was merely a way to be able to calculate the amount of time the bird had been observed. The difficulties with the films led to less observable material and, unfortunately, a rather small data set. The problem could have been solved if the rooks

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had had some time to get use to the equipment, or if they were unaware of being filmed.

## 6. Summary

To summarize, the evidence of a temporal unit guiding perception in humans, is supported by evidence from numerous studies. However, the evidence for a temporal constraint in overt behaviour is not as well established as in perception. According to the results in this study, the perceptual interval in rooks seems to be shorter than in mammals. However, observations of overt perceptual behaviours were next to absent in this study, hence the results cannot be statistically confirmed. In order to firmly establish a temporal integrative mechanism, the study of perception in animals would be beneficial. Although a rather small dataset, the observations of overt behaviours in this study are plenty, and the result point to a shorter duration in rooks compared to the mammals in Gerstner & Goldberg (1994). This suggests that rooks have a lower upper limit of their temporal actions compared to the three seconds proposed for mammals. The result can be explained by faster perception in rooks, or possibly due to their small size, or perhaps even a combination of the two. The ruling factors behind a temporal constant in overt behaviour are not obvious and could possibly have multiple contributing factors.

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Appendix 1.

## Ethogram

| Action | Description (onset: offset) |
|---|---|
| Allopreening | Clean body of another bird with the beak (onset when the head moves: offset when the head is in its originating position) |
| bathing (snow/water) | Bird lies down in snow or water, rustles its feathers and splashes substance on its back (onset when first lying down: offset when sitting/standing and body still ) |
| Billing against object (or ground) | grinding beak on object (onset when the beak starts moving towards object: offset when beak loose contact and the body is in an upright position) |
| Billing with conspecific | grinding beak on another birds beak (onset when the beak starts moving towards bird: offset when beaks are 2 cm or more from each other) |
| Eating | picking up and eating food item (onset when head moves to pick up: offset when item is swallowed) |
| Fluffing | ruffle the feathers (onset on the initial movement to shake: offset when body is still) |
| Flying | 2 or more wing flaps while in the air (onset when feet leaves the ground: offset when feet is on the ground and wings are still ) |
| Flying preparation | crouching down and then jumps up (onset when bird starts crouching: offset with flying behaviour onset) |
| Foraging | Bird use its beak to dig/remove snow from ground (onset when beak starts moving towards ground: offset when beak in its original position) |
| Grabbing/carrying | picking up object with beak (onset when beak starts moving towards the item: offset when item is dropped.) |
| Head movement | movement (in relation to the body) of the head in any direction |
| Head shake | shaking head from side to side (onset when had starts to move:offset when head is still) |
| Jump | jump to reach higher ground or over obstacle (onset when feet leaves ground: offset when feet touches ground) |
| OOS bird | bird is out of sight |
| OOS Body | the body is out of sight (head visible) |
| OOS head | the head of the bird is out of sight |
| Other | unidentified behaviour (or non observable due to quality) |
| Pecking | rapid stabbing motion with beak against object (onset when the head first start moving in the "stabbing" direction: offset when body is same position as when initiating pecking.) |
| Preening | Clean itself with the beak (onset when the head moves: offset when head is still) |
| "Run" | small jumps forward without wing-flapping (onset when the feet leaves the ground in the first small jump: offset when both feet are in contact with ground and body still) |
| Scratching | scratching the body whit one foot (onset when the leg begins to move: offset when the foot is original position ) |

| Behavior | Description |
| --- | --- |
| Sidestep | moving sideways (onset when foot starts moving; offset when foot is still) |
| Sit | Motionless with feet underneath the body on object (ground, branch, water tub) |
| Vocalizing | Vocalization |
| Walk | moving on the ground one step at the time (onset when the leg starts to move; offset when both legs are still) |
| Wing flap | a flapping motion with the wings while on the ground/ or on a stick (onset when the wings start moving; offset when wings stop moving) |
| Wing Jump | one or two powerful flaps with wings to avoid oncoming conspecific or to reach higher ground. (onset when wings start moving; offset when both feet are on the ground again and body is still) |
| Wing stretch | Stretching wings (no flapping!) (onset when wings start to move; offset when wings are still in position alongside the body) |