**Comparing the behavioural organization of head pecking, severe feather pecking, and gentle
feather pecking in domestic turkeys**

Hillary A. Dalton ^{a,b,1*}, Benjamin J. Wood ^{a,c}, Tina M. Widowski ^{a,b}, Michele T. Guerin ^d, Stephanie
Torrey ^{a,b}

^a Department of Animal Biosciences, University of Guelph, 50 Stone Road East, Guelph, Ontario, Canada
N1G 2W1

^b Campbell Centre for the Study of Animal Welfare, University of Guelph, Guelph, Ontario, Canada N1G
2W1

^c Hybrid Turkeys, Suite C, 650 Riverbend Drive, Kitchener, Ontario, Canada N2K 3S2

^d Department of Population Medicine, University of Guelph, 50 Stone Road East, Guelph, Ontario,
Canada N1G 2W1

* Corresponding author: Tel.: +44 191 208 6925; E-mail address: hillary.dalton@newcastle.ac.uk

¹ Present Address: School of Natural and Environmental Sciences, Newcastle University, Newcastle
Upon Tyne, United Kingdom NE1 7RU

Abstract

Detection of behavioural temporal patterns (T-patterns) allows for insight into the organization of behaviours that is not apparent through qualitative analysis of the durations and frequencies of discrete behaviours. In this study, a T-pattern was defined as a reoccurring sequence of ≥ 2 behavioural event types² linked by a non-random critical period of time and occurring more often than expected by chance. This study aimed to identify differences in the behavioural distribution and organization of two forms of injurious pecking, head pecking (HP) and severe feather pecking (SFP), and non-damaging gentle feather pecking (GFP) in domestic turkeys using two analytical methods: T-pattern analysis and a conventional assessment of behavioural frequencies and durations. Video observations of pecking behaviour were obtained from focal samples of domestic male turkeys between 5-15 weeks of age. Each focal sampling observation recorded all behaviours shown by a single turkey 120 seconds (s) before and after the turkey performed HP, GFP, or SFP (241 s total observation length per pecking event). Pecking type had no effect on the number of T-patterns and the frequency of T-pattern occurrences. However, both T-pattern detection and the conventional analysis showed turkeys in observations containing HP tended to be more active with shorter lying durations ($H = 7.36$, $df = 2$, $P = 0.025$), less frequent standing ($H = 5.61$, $df = 2$, $P = 0.061$), and less structured T-patterns (total T-pattern durations: $H = 5.996$, $df = 2$, $P = 0.050$, mean durations: $H = 5.34$, $df = 2$, $P = 0.068$) than turkeys engaged in GFP or SFP. The analyses also showed that turkeys that performed SFP tended to show more frequent GFP than turkeys that performed HP ($H = 5.79$, $df = 2$, $P = 0.055$). However, discrepancies in organization of feeding and foraging behaviour between the two analytical methods highlighted the susceptibility of both methods to behavioural variation between individuals when using small sample sizes. Future research should use T-pattern detection to evaluate age, sex, and environmental differences in the organization of the injurious pecking behaviour in domestic turkeys.

² Behavioural event types: In this study, a behavioural event type was classified as each occurrence of a behavioural event and both the start and end of each occurrence of a behavioural state.

Keywords: Turkeys; Injurious pecking; Severe feather pecking; Head pecking; Gentle feather pecking; T-patterns

1. Introduction

Beak-related activity, such as preening, drinking, feeding, foraging, and pecking directed towards conspecifics or the environment, makes up a large proportion of the behavioural repertoire of domestic turkeys. Specifically, Hughes and Grigor (1996) reported that female turkeys from 1-12 weeks of age spent on average 6% of their total daily activity budget pecking at the plumage and skin of their flock mates. The pecking of another turkey can be defined as being the gentle or severe feather pecking of the body, or aggressive pecking specifically directed towards the head and neck (Sherwin et al., 1999ab; Dalton et al., 2013). Gentle feather pecking (GFP) is defined as a social and investigatory preening of another turkey, typically directed at debris on the plumage. This behaviour is performed without force and causes no damage to the pecked turkey (Savory, 1995; Duggan et al., 2014). In contrast, head pecking (HP) and severe feather pecking (SFP) are classified as injurious pecking as these behaviours can cause tissue damage and mortality resulting in declines in both productivity and welfare (Lewis et al., 1998; Krautwald-Junghanns et al., 2011; Dalton et al., 2013; Duggan et al., 2014). HP is considered to be an aggressive act that is targeted at the head, neck, and snood of another turkey (Savory, 1995; Sherwin et al., 1999a; Buchwalder and Huber-Eicher, 2003). SFP is the repeated, forceful pecking and pulling of the plumage and/or skin of another turkey, with or without feather removal, and often results in plumage and tissue damage to the recipient (Savory, 1995; Duggan et al., 2014). The underlying motivation of SFP in poultry is believed to represent the re-directed ground pecks of foraging behaviour in environmental conditions lacking appropriate stimuli (Hughes and Grigor, 1996; Sherwin et al., 1999a; Dixon et al., 2008). Several studies have shown the provision of foraging substrates can successfully reduce damaging

pecking injuries in groups of domestic turkeys (Crowe and Forbes, 1999; Sherwin et al., 1999ab; Martrenchar et al., 2001; Berk et al., 2017).

To find practical solutions to behavioural problems, animal behaviour and welfare research is incorporating innovative statistical approaches to provide new information about the underlying structure of damaging behaviour and the behavioural consequences of poor animal welfare. Using a top-down approach, a pattern-detection algorithm, such as the THEME software package (Magnusson, 2000), uses the order and timing of individual behaviours to identify recurring temporal behavioural patterns (T-patterns) within a sequence of behaviours (Asher et al., 2009; Cassarubea et al., 2015). T-patterns can be defined as a reoccurring sequence of ≥ 2 behavioural elements that occur more frequently than expected by chance and are linked together by a non-random critical period of time (Magnusson, 2000). Temporal pattern detection has been successful at revealing temporal relationships among behaviours that cannot be detected when a continuous behavioural sequence is divided into its discrete elements by conventional qualitative analysis. Animals experiencing good welfare are characterized as possessing complex repertoires of behavioural patterns (*i.e.*, low behavioural T-pattern structure) that they exhibit with the same likelihood (*i.e.*, high T-pattern frequency), and are capable of varying their behaviour (*i.e.*, high T-pattern variety) when encountering novel stimuli within their environment (María et al., 2004; Asher et al., 2009; Sinclair et al., 2015). In contrast, animals with compromised welfare housed under poorer social and/or environmental conditions might show only a few different behaviours overall and relatively simple, invariable behavioural reactions to new environmental stimuli (María et al., 2004; Asher et al., 2009; Brilot et al., 2009; Sinclair et al., 2015). For instance, Sinclair et al. (2015) showed that turkeys with footpad dermatitis had more frequent, complex, and varied T-patterns on dry vs. wet litter and greater T-pattern frequency and variation when provided analgesic treatment. Temporal analysis by THEME has also been used in mice and starling research to show that individuals exhibiting abnormal repetitive behaviours spent more time engaged in the same, few invariant behavioural patterns (Bonasera et al., 2008; Brilot et al., 2009; Feenders and Bateson, 2012). When applied along with descriptive analyses of behaviour, we expect multivariate T-pattern detection will provide new insight into the

organization of injurious pecking behaviour in turkeys for a better understanding of why outbreaks occur and how to prevent their reoccurrence.

The objective of this study was to identify differences in the behavioural distribution and organization of HP, SFP, and GFP in domestic male turkeys using two analytical methods: T-pattern analysis and a conventional assessment of behavioural frequencies and durations. Based on the existing literature on injurious pecking in turkeys, we hypothesized that the performance of abnormal injurious pecking behaviour, such as SFP and HP, would show more structured, yet less variable and frequent occurrences of behavioural T-patterns over time than bouts of GFP, a non-damaging social preening behaviour (Sherwin et al., 1999ab; Buchwalder and Huber-Eicher, 2003; Duggan et al., 2014).

2. Materials and methods

The use of all animals in this study was approved by the University of Guelph Animal Care Committee and adheres to the guidelines of the University of Guelph Animal Care Policy and the Canadian Council on Animal Care (CCAC, 2009).

2.1. Animals and experimental design

We evaluated the pecking behaviour of 127 focal observations of infrared beak-treated White Hybrid converter heavy strain male turkeys from 5-15 weeks of age. The observations in this study were collected as part of a larger observational project (Duggan et al., 2014). The video recordings were taken in eight commercial barns (four closed-sided and four curtain-sided; 9-20 observations per barn) at four ages: 5-6 (20 observations), 7-9 (23), 11-12 (40), and 13-15 (44) weeks of age. Each barn contained approximately 5000-7500 male turkeys and all barns were located at a single commercial facility in southwestern Ontario. At each age, video recordings were taken in all barns on a single day and recorded 1.5 h of normal activity between 1000 to 1500 h. On each filming day, the positions of the cameras in

each barn were randomly selected in an attempt to increase the number of birds sampled within each barn. Each camera was positioned approximately 2.13m above the ground and filmed an ~41 m² viewpoint of each barn (Duggan et al., 2014).

2.2. Behavioural scoring

Individual turkeys were identified for focal observations if the turkey performed GFP, SFP, or HP behaviour during the video recordings and had not previously sampled on that particular filming date. For each pecking observation, the sequence of behaviours of the focal turkey was scored continuously in Noldus Observer XT 11 (Noldus Information Technology, Wageningen, NL) for 120 s before and after the pinpointed pecking event occurred, including any other occurrences of pecking behaviour (241 s total observation length). An observation could include more than one type of pecking behaviour; however, the observation was classified based on the pecking type that occurred at the 121 s time point in the observation. There were a total of 127 observations of pecking behaviour consisting of 74 GFP, 27 SFP, and 26 HP observations.

The behaviour of the turkeys was scored using an ethogram of 17 behaviours, which included eleven states (feeding/foraging, drinking, walking, standing, lying, preening, dust bathing, displaying, other, and out-of-view) and six behavioural events (scratch flock mate, SFP flock mate, GFP flock mate, HP flock mate, receive peck, and peck object) that occurred concomitantly with the behavioural states (Table 1). The postural states (standing, lying, and walking) and active behavioural states (feeding/foraging, drinking, preening, dust bathing, and displaying) were each scored exclusively, so only one state from each category could occur at a single time point. The ethogram also included the states 'other' to score any behaviour not described in the ethogram and 'out-of-view' for when a focal turkey moved out of the recording area or was blocked from view by another turkey (Table 1). Both 'other' and 'out-of-view' were scored exclusively of the alternative behavioural states or events. SFP of a flock mate was defined as a focal turkey directing its beak towards the plumage or skin of another turkey and visibly

pulling on the plumage or skin of the recipient turkey. GFP of a flock mate occurred when a focal turkey directed its beak towards another turkey's feathers while opening and closing its beak on the feathers without any pulling motion. An aggressive HP was defined as a focal turkey directing its beak in a swift motion towards the head, neck, and/or snood of another turkey with or without pulling on the skin of the recipient turkey (Table 1).

2.3. Data processing

2.3.1. Conventional behavioural assessment

Using Observer XT, the total time, frequency, and mean duration was calculated for each behavioural state in each of the observation files. The total frequencies of the behavioural events were also determined for each observation.

2.3.2. T-pattern detection

The raw Observer observation files were transferred into THEME version 5 (Noldus Information Technology, Wageningen, NL) for detection of the hidden temporal structures (T-patterns) within the pecking behavioural sequences (Magnusson, 2000; Cassarubea et al., 2015). To be analyzed by THEME, the observation files were first converted into text files using Noldus Pattern Vision DEPxp 3.1.1.1 (PatternVision Ltd, Reykjavik, ISL). THEME labeled each occurrence of a behavioural event and both the start and end of each behavioural state as time-stamped behavioural event types within the observation (Cassarubea et al., 2015). A T-pattern was defined as a recurring combination of two or more behavioural event types that were linked by a non-random critical period of time (See Magnusson, 2000 for further detail). For our study, an identified T-pattern occurred at least three times within an observation with a non-random significance of $P < 0.005$ (Magnusson, 2000; Merlet et al., 2005). THEME computed the number of detected T-patterns within each observation (*i.e.*, T-pattern variety) and the total frequency of all T-pattern occurrences (*i.e.*, T-pattern frequency), the average total duration of the T-patterns, and the

mean duration of occurrences of the detected T-patterns (*i.e.*, T-pattern structure) in each file for later comparison between the three pecking types (Hocking et al., 2007; Sinclair et al., 2015). Two observations (one HP & one GFP observation) could not be converted in Pattern Vision and were excluded from analysis in THEME.

2.4. Statistical analysis

All statistical procedures were performed in SAS (SAS 9.2, 2007) and SPSS (IBM SPSS Statistics Version 24). For the conventional analysis, the dependent variables for the behavioural states were the total time spent performing a particular behaviour (total duration), the frequency (number of occurrences) of each behaviour, and the mean duration of each occurrence of a behaviour. The dependent variables for the behavioural events from the conventional assessment were the frequency (number) of occurrences of each behavioural event. Dust bathing did not occur within any of the observation files so this behaviour was not included in the conventional or THEME analyses.

The dependent variables from THEME analysis were the number and the total frequency of all T-pattern occurrences, the average total duration of the T-patterns, and the mean duration (s/occurrence) of T-pattern occurrences in each file. The behavioural data from both the conventional and THEME analyses had unbalanced sample sizes and non-normal, right-skewed distributions with equal variances for the three pecking types, which could not be normalized using logarithm, square root, or cube root transformations. As a result, the dependent data from the conventional and THEME analyses were analyzed separately in SAS using Kruskal-Wallis H tests with the type of pecking observation (GFP, SFP, or HP) as the fixed effect. When a significant type effect was detected, a post-hoc Dunn's test using rank sums with a Bonferroni correction for multiple tests was performed in SPSS for pair-wise comparisons between pecking types. Significant effects were detected at $P < 0.05$ and the tendency of an effect was interpreted when the P -value was < 0.10 .

3. Results

The mean values ($\pm$ SEM) for the mean duration, total duration, and frequency of the different behavioural states are shown for the three types of pecking observations in Table 2. Turkeys spent more total time lying in observations with SFP than in observations containing HP ($Z = -2.67$, $P = 0.023$; Table 2). Within observations containing HP, turkeys had significantly greater total durations of time feeding and foraging than turkeys engaged in GFP or SFP ($H = 6.08$, $df = 2$, $P = 0.048$; Table 2). Post-hoc comparison of the pecking types showed a trend for turkeys exhibiting HP to have longer durations ($Z = 2.36$, $P = 0.055$) and a higher frequency of feeding and foraging ($Z = 2.97$, $P = 0.01$) than SFP turkeys (Table 2). Additionally, observations with HP tended to have more bouts of standing than turkeys engaged in GFP or SFP ($H = 5.61$, $df = 2$, $P = 0.061$; Table 2). The frequency of HP or SFP did not significantly differ between the three types of pecking observations (HP: $H = 3.13$, $df = 2$, $P = 0.21$, SFP: $H = 1.04$, $df = 2$, $P = 0.60$). However, observations containing GFP and SFP tended to have more occurrences of GFP (1.73 ± 0.01 and 2.00 ± 0.32 GFP respectively; mean $\pm$ SEM) than observations with HP, which had few bouts of GFP (1.00 ± 0.00 ; $H = 5.79$, $df = 2$, $P = 0.055$). No differences amongst the three pecking types were detected in the total durations, mean durations, and frequencies of drinking ($P = 0.380$), preening ($P = 0.221$), walking ($P = 0.115$), displaying ($P = 0.413$), other ($P = 0.541$), and out-of-view ($P = 0.509$)². Similarly, pecking type had no effect on the frequencies of scratch flock mate ($P = 0.850$), receive peck ($P = 0.526$), and peck object behaviour ($P = 0.683$) in these observations.

Three hundred and twenty-nine non-random T-patterns were detected in 15 HP, 39 GFP, and 11 SFP classified observations. No significant T-patterns were detected in 10 HP, 35 GFP, and 15 SFP observations of these pecking behaviours. The mean number, frequency, total and mean durations of significant T-patterns for the three types of pecking are presented in Table 3. There was no difference amongst the three pecking types in the number of unique temporal patterns ($H = 0.50$, $df = 2$, $P = 0.78$)

² The smallest P-value is presented from the three Kruskal-Wallis tests completed for each behavioural state (*i.e.*, mean duration, total duration, and frequency) by pecking type.

and the frequencies with which these patterns occurred ($H = 0.23$, $df = 2$, $P = 0.89$; Table 3). However, both the total duration of T-patterns ($H = 5.996$, $df = 2$, $P = 0.050$) and the mean duration of T-pattern occurrences ($H = 5.34$, $df = 2$, $P = 0.068$) showed a tendency to be shorter within observations with HP than those containing GFP or SFP (Table 3). Of the 70 non-random T-patterns detected in the observations with HP, over 62% were a combination of standing and walking (25.71%), standing with or without feeding/foraging (14.29%), and patterns of standing, walking, and HP (8.57%; Table 4). The most common of the 211 detected T-patterns in the observations with GFP were sequences of feeding/foraging and standing (37.91%), feeding/foraging and other behaviour (8.53%), standing (8.06%), and lying (6.64%; Table 4). Within the observations containing SFP, the largest proportions of the 48 significant T-patterns were composed of feeding/foraging and standing (29.17%), lying (18.75%), drinking and standing (10.42%), and sequences of scratching, standing, and GFP behaviour (14.58%; Table 4).

4. Discussion

Injurious pecking poses a serious problem to the welfare of modern turkeys, but the causation and development of the different forms of this damaging behaviour are still poorly understood (Krautwald-Junghanns et al., 2011; Dalton et al., 2013; Duggan et al., 2014). To gain a better understanding of injurious pecking behaviour in turkeys, we designed this experiment to study the patterns in the behavioural sequences of GFP and two forms of injurious pecking, HP and SFP. We hypothesized that the three pecking types would have a different organizational structure with observations of abnormal damaging pecking, SFP and HP, being more structured, but with less variable and frequent occurrences of behavioural patterns over time than observations containing GFP, a non-damaging social behaviour (Sherwin et al., 1999ab; Buchwalder and Huber-Eicher, 2003; Duggan et al., 2014). The results from the T-pattern analysis showed pecking type had no effect on the variety or frequency of unique temporal patterns in the behavioural sequences of these male turkeys. However, the two analytical approaches,

conventional qualitative assessment and THEME analysis, both identified similar differences in the structure of lying, standing, and GFP behaviour amongst the different pecking types. The motivational basis of the different types of injurious pecking seen in turkeys has been primarily adopted from laying hen research. This research suggests the cause of SFP outbreaks in poultry is multi-factorial, but primarily represents re-directed foraging behaviour due to a lack of suitable environmental stimuli (Hughes and Grigor, 1996; Sherwin et al., 1999a; Dixon et al., 2008). GFP in turkeys is considered the investigatory preening of debris on the plumage of flock mates (Savory, 1995; Duggan et al., 2014). In contrast, HP in turkeys is considered an act of aggression (Savory, 1995; Sherwin et al., 1999a; Buchwalder and Huber-Eicher, 2003).

The conventional analysis showed that when turkeys were engaged in HP, they appeared to be more active, spending less time lying with more frequent bouts of standing behaviour, compared to when turkeys engaged in other types of pecking. In contrast, when turkeys exhibited SFP, this type of pecking was associated with less active behaviour with longer lying durations and less frequent standing. Similarly, THEME identified standing as a component of the four most common T-patterns seen in observations of turkeys engaged in HP. THEME also showed that sequences of lying behaviour made up 18.75% and 6.64% of T-patterns detected in the observations containing SFP or GFP. Furthermore, the T-patterns in the observations containing HP tended to have both shorter total and mean pattern durations than the T-patterns for turkeys engaged in GFP or SFP. This suggests that behavioural organization of HP is less structured than the behaviour of GFP or SFP. Our results are consistent with previous research showing turkey flocks can become more active and perform HP following environmental or social disturbances in order to settle the flock and re-establish the dominance hierarchy (Cunningham et al., 1992; Buchwalder and Huber-Eicher, 2003, 2004). The positive association between activity and HP behaviour in turkeys suggests that strategies to prevent social and environmental disturbances could reduce outbreaks of HP in commercial flocks.

A tendency for turkeys performing GFP or SFP to show more GFP behaviour was also seen in the results from both the conventional and T-pattern analyses. In the observations of SFP, almost 15% of all

significant T-patterns included GFP. The link between GFP and SFP in these observations supports the idea of a shared origin for these two pecking behaviours in poultry (Hughes and Grigor, 1996; McAdie and Keeling, 2002; Daigle et al., 2015). SFP and GFP are both directed towards the plumage on the wings, back, and tail of another turkey. SFP is also thought to develop from investigatory GFP that becomes more forceful and often results in feather removal with additional plumage and/or tissue damage (Savory, 1995; Hughes and Grigor, 1996; Dalton et al., 2013). A comparative study of traditional and commercial line turkeys by Busayi et al. (2006) showed a similar pattern of development for SFP and GFP in both lines of turkeys from three to nine weeks of age. The incidence of GFP and SFP were most frequent at three and six weeks of age in both lines then declined at nine weeks of age (Busayi et al., 2006). In contrast, Dixon et al. (2008) found that the motor patterns comprising SFP and GFP in laying hens were distinctly different with SFP pecks being more morphologically similar to foraging pecks than GFP pecks, which suggests separate motivational origins for these two bird-directed pecking behaviours. However, Newberry et al. (2007) suggested the relationship between SFP and GFP in poultry is more complex. When GFP is divided into stereotyped or exploratory GFP, the performance of exploratory GFP is more closely correlated with SFP in young hens (Newberry et al., 2007). In domestic turkeys, further work is needed to understand how GFP and SFP develop in turkeys grown to a later age under commercial conditions. In addition, research in turkeys should focus on determining the origins of SFP and GFP to ascertain if SFP in turkeys results from certain factors causing the performance of GFP to become forceful.

Although there were many consistencies, THEME and the conventional analyses produced conflicting results for the structure of feeding and foraging behaviour in each of the three pecking types. The conventional assessment showed turkeys performing HP had longer total durations and more frequent occurrences of feeding and foraging than turkeys exhibiting GFP or SFP. However, only 14.29% of the most common T-patterns in the HP observations included feeding and foraging. THEME showed feeding and foraging behaviour was a component of 37.91% and 29.17% of T-patterns detected in the GFP and SFP observations. SFP in poultry is believed to primarily represent highly-motivated ground foraging that

has been re-directed in barren environmental conditions and the provision of foraging substrates has been shown to reduce SFP injuries in turkey flocks (Sherwin et al., 1999ab; Dixon et al., 2008; Duggan et al., 2014; Berk et al., 2017). Therefore, we would predict feeding and foraging to be more common in behavioural sequences of SFP than HP. However, frequency of HP in growing turkeys has also been shown to decrease when a foraging enrichment, such as straw or vegetable matter, is provided (Sherwin et al., 1999a; Martrenchar et al., 2001). Furthermore, limited access or insufficient distribution of feeder space has been linked to heightened aggression in broiler chickens during feeding, which might also explain the higher incidence of HP during periods of feeding and foraging in this study (Olukosi et al., 2002; Leone and Estévez, 2008). Unlike T-pattern detection, conventional assessment of behavioural durations and frequencies focuses on single behaviours instead of patterns of behaviours, which might explain the additive, but not directly equivalent feeding/foraging findings from these complimentary analytical methods (Hocking et al., 2007). These results also likely reflect the sensitivity of conventional analysis to behavioural variation between individual pecking records, which was amplified by the small sample sizes for both HP and SFP observations in this study. However, the grouping of feeding and foraging behaviour together in this study might have ultimately incorrectly linked two discrete behaviours, which may show distinct behavioural patterns and associations with pecking behaviour in turkeys.

Another potential limitation for the interpretation of this study's findings is the large individual variability in the number of detected T-patterns with 60 of the 125 pecking observations in this study showing no significant T-patterns. Martaresche et al. (2000) theorized that pattern variation between individuals represents individual adaptation strategies in the performance of a particular behaviour. A reduction in the variation in the number of T-patterns between animals might also identify those individuals experiencing poor welfare from stress or illness, and more likely to express abnormal behaviour, as those exhibiting a greater number of invariant behavioural sequences (T-patterns) in their behaviour (María et al., 2004; Asher et al., 2009; Brilot et al., 2009; Sinclair et al., 2015). In this study, observations containing the two abnormal injurious pecking behaviours, SFP and HP, had the fewest

observations containing no T-patterns (SFP: 15 observations, HP: 10) whereas GFP, a non-damaging social pecking behaviour, had the highest number of observations without predictable behavioural T-patterns associated with its performance (35). However, the design of this study, including the ~4 min observation length and the default THEME analysis detection parameters, such as the minimum of three occurrences of a T-pattern in each observation, might have ultimately been unsuitable for detecting reoccurring temporal patterns of these pecking behaviours. Given the combination of the large variation in detected T-patterns and the small sample sizes for two injurious pecking types in this study, the results from the THEME analysis of HP and SFP must be treated as exploratory. Additionally, it should be recognized that the trends towards significance detected in this study might simply be artifacts of the small HP and GFP sample sizes, which could change drastically in either direction when more observations are considered.

In summary, multivariate T-pattern detection, alongside the conventional qualitative behavioural assessment, provided a complimentary examination of the organization of pecking behaviour in these domestic male turkeys. Conventional and T-pattern analysis identified similar distinguishing features in active behaviours and GFP amongst turkeys engaged in HP, GFP, or SFP. Yet these analyses gave conflicting results on the structure of feeding and foraging behaviour amongst the three pecking types. Future research should continue to employ analytical methods, such as T-pattern detection, for a complete representation of age, sex, and environmental differences in the organization of injurious pecking behaviour in domestic turkeys.

Acknowledgements

Thank you to Ashleigh Arnone for completing the behavioural annotations for this study and many thanks to Graham Duggan and his co-authors for providing access to this data for our analysis. This study was supported by the Ontario Ministry of Agriculture, Food, and Rural Affairs; Agriculture and Agri-Food Canada; the Canadian Poultry Research Council; and the Poultry Industry Council.

References

- Asher, L., Collins, L.M., Ortiz-Pelaez, A., Drewe, J.A., Nicol, C.J., Pfeiffer, D.U., 2009. Recent advances in the analysis of behavioural organization and interpretation as indicators of animal welfare. *J. R. Soc. Interface* 6: 1103-1109. <https://dx.doi.org/10.1098/rsif.2009.0221>
- Berk, J., Stehle, E., Bartels, T., 2017. Enrichment device – a way to reduce injurious pecking in fattening turkeys with intact beaks? *Berliner und Munchener Tierarztliche Wochenschrift* 130: 230-240. [Abstract; Article in German].
- Bonasera, S.J., Schenk, A.K., Luxenburg, E.J., Tecott, L.H. 2008. A novel method for automatic quantification of psycho stimulant-evoked route-tracing stereotypy: application to *Mus musculus*. *Psychopharmacology* 196: 591-602. <https://dx.doi.org/10.1007/s00213-007-0994-6>
- Brilot, B.O., Asher, L., Feenders, G., Bateson, M., 2009. Quantification of abnormal repetitive behaviour in captive European starlings (*Sturnus vulgaris*). *Behav. Process.* 82: 256-264. <https://doi.org/10.1016/j.beproc.2009.07.003>
- Buchwalder, T., Huber-Eicher, B., 2003. A brief report on aggressive interactions within and between groups of domestic turkeys (*Meleagris gallopavo*). *Appl. Anim. Behav. Sci.* 84: 75-80. [https://doi.org/10.1016/S0168-1591\(03\)00149-7](https://doi.org/10.1016/S0168-1591(03)00149-7)
- Buchwalder, T., Huber-Eicher, B., 2004. Effect of increased floor space on aggressive behaviour in male turkeys (*Meleagris gallopavo*). *Appl. Anim. Behav. Sci.* 89: 207-214. <https://doi.org/10.1016/j.applanim.2004.07.001>
- Busayi, R.M., Channing, C.E., Hocking, P.M. 2006. Comparisons of damaging feather pecking and time budgets in male and female turkeys of a traditional breed and a genetically selected male line. *Appl. Anim. Behav. Sci.* 96: 281-292. <https://doi.org/10.1016/j.applanim.2005.06.007>
- Canadian Council on Animal Care (CCAC), 2009. CCAC guidelines on: the care and use of farm animals in research, teaching and testing. Canadian Council on Animal Care, Ottawa, Canada.

385 Cassarubea, M., Jonsson, G.K., Faulisi, F., Sorbera, F., Di Giovanni, G., Benigno, A., Crescimanno,
386 G., M.S., Magnusson. 2015. T-pattern analysis for the study of temporal structure of animal and
387 human behaviour: A comprehensive review. *J. Neurosci. Methods* 239: 34-46.
388 <https://dx.doi.org/10.1016/j.jneumeth.2014.09.024>

389 Crowe, R., Forbes, J.M. 1999. Effects of four different environmental enrichment treatments on pecking
390 behaviour in turkeys. *Br. Poult. Sci.* 40: S11–S12. <http://dx.doi.org/10.1080/00071669986558>

391 Cunningham, D.L., Buhr, R.J., Mamputu, M., 1992. Beak trimming and sex effects on behaviour and
392 performance traits of large white turkeys. *Poult. Sci.* 71: 1606-1614.
393 <https://doi.org/10.3382/ps.0711606>

394 Daigle, C.L., Rodenburg, T.B., Bolhuis, J.E., Swanson, J.C., Siegford, J.M., 2015. Individual consistency
395 of feather pecking behaviour in laying hens: once a feather pecker always a feather pecker? *Front.*
396 *Vet. Sci.* 2: 1-12. <https://doi.org/10.3389/fvets.2015.00006>

397 Dalton, H.A., Wood, B.J., Torrey, S., 2013. Injurious pecking in turkeys: development, causes, and
398 potential solutions. *World's Poult. Sci. J.* 69: 865-875.
399 <https://doi.org/10.1017/S004393391300086X>

400 Dixon, L.M., Duncan, I.J.H., Mason, G., 2008. What's in a peck? Using fixed action pattern morphology
401 to identify the motivational basis of abnormal feather-pecking behaviour. *Anim. Behav.* 76: 1035-
402 1042. <https://doi.org/10.1016/j.anbehav.2008.06.001>

403 Duggan, G., Widowski, T., Quinton, M., Torrey, S., 2014. The development of injurious pecking in a
404 commercial turkey facility. *J. Appl. Poult. Res.* 23: 280-290. [https://dx.doi.org/10.3382/japr.2013-](https://dx.doi.org/10.3382/japr.2013-00860)
405 00860

406 Feenders, G., Bateson, M., 2012. The development of stereotypic behaviour in caged European
407 starlings, *Sturnus vulgaris*. *Dev. Psychobiol.* 54: 773-784. <https://dx.doi.org/10.1002/dev.20623>

408 Hocking, P.M., Rutherford, K.M.D., Picard, M., 2007. Comparison of time-based frequencies, fractal
409 analysis, and T-patterns for assessing behavioural changes in broiler breeders fed on two diets at

410 two levels of feed restriction: a case study. Appl. Anim. Behav. Sci. 104: 37-48.
 411 <https://doi.org/10.1016/j.applanim.2006.04.023>
 412 Hughes, B.O., Grigor, P.N., 1996. Behavioural time-budgets and beak related behaviour in floor-housed
 413 turkey. Anim. Welf. 5: 189-198.
 414 Krautwald-Junghanns, M.E., Ellerich, R., Mitterer-Istyagin, H., Ludewig, M., Fehlhaber, K., Schuster, E.,
 415 Berk, J., Dressel, A., Petermann, S., Kruse, W., Noack, U., Albrecht, K., Bartels, T., 2011a.
 416 Examination of the prevalence of skin injuries in debeaked fattened turkeys. Berliner und
 417 Munchener Tierarztliche Wochenschrift 124: 8-16. [Abstract; Article in German].
 418 Leone, E.H., Estévez, I., 2008. Space use according to the distribution of resources and level of
 419 competition. Poult. Sci. 87: 3-13. <https://doi.org/10.3382/ps.2007-00026>
 420 Lewis, P.D., Perry, G.C., Sherwin, C.M., 1998. Effect of photoperiod and light intensity on the
 421 performance of intact male turkeys. Anim. Sci. 66: 759-767.
 422 <https://doi.org/10.1017/S1357729800009358>
 423 Magnusson, M.S., 2000. Discovering hidden time patterns in behaviour: T-patterns and their detection.
 424 Behav. Res. Methods Instrum. Comput. 32: 93-110. <https://doi.org/10.3758/BF03200792>
 425 María, G.A., Escós, J., Alados, C.L. 2004. Complexity of behavioural sequences and their relation to
 426 stress conditions in chickens (*Gallus gallus domesticus*): a noninvasive technique to evaluate
 427 animal welfare. Appl. Anim. Behav. Sci. 86: 93-104.
 428 <https://doi.org/10.1016/j.applanim.2003.11.012>
 429 Martaresche, M., Le Fur, C., Magnusson, M., Faure, J.M., Picard, M., 2000. Time structure of
 430 behavioural patterns related to feed pecking in chicks. Physiol. Behav. 70: 443-451.
 431 [https://doi.org/10.1016/S0031-9384\(00\)00283-3](https://doi.org/10.1016/S0031-9384(00)00283-3)
 432• Martrenchar, A., Huonnic, D., Cotte, J.P., 2001. Influence of environmental enrichment on injurious
 433 pecking and perching behaviour in young turkeys. Brit. Poult. Sci. 42: 161-170.
 434 <https://doi.org/10.1080/00071660120048393>

- McAdie, T.M., Keeling, L.J., 2002. The social transmission of feather pecking in laying hens: effects of environment and age. *Appl. Anim. Behav. Sci.* 75: 147-157. [https://dx.doi.org/10.1016/S0168-1591\(01\)00182-4](https://dx.doi.org/10.1016/S0168-1591(01)00182-4)
- Merlet, F., Puterflam, J., Faure J.M., Hocking, P.M., Magnusson, M.S., Picard, M., 2005. Detection and comparison of time patterns of behaviours of two broiler breeder genotypes fed ad libitum and two levels of feed restriction. *Appl. Anim. Behav. Sci.* 94: 255-271. <https://doi.org/10.1016/j.applanim.2005.02.014>
- Newberry, R.C., Keeling, L., Estevez, I., Bilcik, B., 2007. Behaviour when young as a predictor of severe feather pecking in adult laying hens: the redirected foraging hypothesis revisited. *Appl. Anim. Behav. Sci.* 107: 262-274. <https://doi.org/10.1016/j.applanim.2006.10.010>
- Olukosi, O.A., Daniyan, O.C., Matanmi, O., 2002. Effects of feeder space allowance on agonistic behaviour and growth performance of broilers (short communication). *Arch. Tierz. Dummerstorf* 45: 205-209.
- Savory, C.J., 1995. Feather pecking and cannibalism. *World's Poult. Sci. J.* 51: 215-219. <https://doi.org/10.1079/WPS19950016>
- Sinclair, A., Weber Wyneken, C., Veldkamp, T., Vinco, L.J., Hocking, P.M., 2015. Behavioural assessment of pain in commercial turkeys (*Meleagris gallopavo*) with foot pad dermatitis. *Brit. Poult. Sci.* 56: 511-521. <https://dx.doi.org/10.1080/00071668.2015.1077204>
- Sherwin, C.M., Lewis, P.D., Perry, G.C., 1999a. Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. *Brit. Poult. Sci.* 40: 592-598. <http://dx.doi.org/10.1080/00071669986954>
- Sherwin, Lewis, P.D., Perry, G.C., 1999b. The effects of environmental enrichment and intermittent lighting on the behaviour and welfare of male domestic turkeys. *Appl. Anim. Behav. Sci.* 62: 319-333. [https://doi.org/10.1016/S0168-1591\(98\)00215-9](https://doi.org/10.1016/S0168-1591(98)00215-9)

Table 1. An ethogram containing the 17 behavioural states and events scored from the 241 s focal observations of the pecking behaviour of male turkeys between 5-15 weeks of age. All of the listed behaviours were included in both the conventional and THEME analyses.

Table 2. The average total duration (s), mean duration (s), and frequency (n) ($\pm$ SEM) of the behavioural states that varied by pecking type during the 241 s focal observations of the pecking behaviour of male turkeys between 5-15 weeks of age. The behaviour of a focal turkey was observed 120 s before and after a focal male turkey engaged in GFP, SFP, or HP.

Table 3. The mean values ($\pm$ SEM) for the total number of different non-random behavioural T-patterns, total number of pattern occurrences, and the total and mean durations of the T-patterns from THEME analysis of focal observations 120 s before and after male turkeys exhibited either GFP, SFP, or HP (total length of each observation: 241 s).

Table 4. The four most frequent types of different, non-random behavioural T-patterns for the three types of pecking observations, including the total number of pattern occurrences of each type of T-pattern and the percentage composition of each T-pattern type amongst all detected T-patterns. T-patterns were detected in THEME analysis of focal observations 120 s before and after male turkeys exhibited GFP, SFP, or HP (total length of each observation: 241 s).

Table 1. An ethogram containing the 17 behavioural states and events scored from the 241 s focal observations of the pecking behaviour of male turkeys between 5-15 weeks of age. All of the listed behaviours were included in both the conventional and THEME analyses.

Behaviour	Description
<u>Behavioural States</u>	
Feeding/Foraging	The turkey has its head and/or beak in the pan feeder or the turkey pecks at litter with beak and/or scratches at litter with feet
Drinking	The turkey has its head and/or beak in the bell drinker
Walking	The turkey takes steps, placing one foot in front of the other
Standing	The turkey is immobile while standing on its feet
Lying	The turkey is resting on its breast on the ground
Preening	The turkey directs its beak at its own feathers, usually accompanied with ptero-erection
Dust bathing	The turkey is in the lying position while flicking litter up into its feathers using its wings
Displaying	While standing and/or walking, the turkey erects the feathers on its back, raises its tail feathers, and drops its wings forwards
Other	Any other behaviour not described above
Out of View	The turkey moves out of the recording area or is blocked by another turkey from the camera's view
<u>Behavioural Events</u>	
Scratch Flock Mate	The turkey directs its claws at another turkey and makes a swiping motion from front to back
SFP Flock Mate ¹	The turkey directs its beak towards another turkey's feathers or skin while visibly pulling on the feathers and/or skin with its beak
GFP Flock Mate ¹	The turkey directs its beak towards another turkey's feathers while opening and closing its beak on the feathers without any pulling motion
HP Flock Mate ¹	The turkey directs its beak in a swift motion towards the head and/or neck of another turkey with or without pulling on the skin of the recipient turkey
Receive Peck	The turkey is the recipient of a peck from another turkey's beak
Peck Environment	The turkey directs its beak at objects within the barn, including the play pit balls, feeders, drinkers, walls, and beams

¹ Gentle feather pecking (GFP), severe feather pecking (SFP), and head pecking (HP)

Table 2. The average total duration (s), mean duration (s), and frequency (n) ($\pm$ SEM) of the behavioural states that varied by pecking type during the 241 s focal observations of the pecking behaviour of male turkeys between 5-15 weeks of age. The behaviour of a focal turkey was observed 120 s before and after a focal male turkey engaged in GFP, SFP, or HP¹.

Behaviour	Pecking Type	Total duration (s)	Mean Duration (s)	Frequency (n)
Standing	GFP	47.09 $\pm$ 0.69	16.36 $\pm$ 0.27	3.07 $\pm$ 0.03 ^d
	SFP	41.41 $\pm$ 1.64	18.50 $\pm$ 0.66	2.52 $\pm$ 0.08 ^e
	HP	58.09 $\pm$ 2.71	14.53 $\pm$ 0.52	3.80 $\pm$ 0.10 ^c
Lying	GFP	123.51 $\pm$ 0.80 ^{ab}	48.44 $\pm$ 0.39	3.10 $\pm$ 0.02
	SFP	138.76 $\pm$ 2.40 ^a	44.16 $\pm$ 1.03	3.68 $\pm$ 0.07
	HP	96.67 $\pm$ 2.39 ^b	37.67 $\pm$ 1.00	3.00 $\pm$ 0.08
Feeding & Foraging	GFP	53.42 $\pm$ 1.08 ^{abd}	30.07 $\pm$ 0.74	2.51 $\pm$ 0.05 ^b
	SFP	32.78 $\pm$ 3.19 ^{bcd}	17.39 $\pm$ 0.85	1.71 $\pm$ 0.14 ^b
	HP	72.89 $\pm$ 5.40 ^{ac}	32.66 $\pm$ 2.34	3.09 $\pm$ 0.17 ^a

¹ Gentle feather pecking (GFP), severe feather pecking (SFP), and head pecking (HP)

Within a column, for each behaviour, values with different superscripts differ, $a \pm b$, $P < 0.05$; $c \pm d \pm e$, $P < 0.10$

Table 3. The mean values ($\pm$ SEM) for the total number of different non-random behavioural T-patterns¹, total number of pattern occurrences, and the total and mean durations of the T-patterns from THEME analysis of focal observations 120 s before and after male turkeys exhibited either GFP, SFP, or HP² (total length of each observation: 241 s).

THEME Variables	Pecking Type		
	GFP	SFP	HP
Number of Different Patterns (n)	5.46 $\pm$ 0.23	4.36 $\pm$ 0.46	4.67 $\pm$ 0.31
Pattern Occurrences (n)	23.18 $\pm$ 1.13	21.27 $\pm$ 2.94	16.20 $\pm$ 1.19
Total Duration of Patterns (s)	27.72 $\pm$ 0.55 ^d	27.05 $\pm$ 3.07 ^d	12.19 $\pm$ 0.59 ^c
Mean Duration of a Pattern Occurrence (s)	7.21 $\pm$ 0.15 ^d	7.76 $\pm$ 1.02 ^d	3.70 $\pm$ 0.17 ^c

¹ A temporal sequence of two or more behavioural event types occurring more often than expected by chance ($P < 0.005$).

² Gentle feather pecking (GFP), severe feather pecking (SFP), and head pecking (HP)

Within a row, values with different superscripts differ, a $\pm$ b, $P < 0.05$; c $\pm$ d $\pm$ e, $P < 0.10$

Table 4. The four most frequent types of different, non-random behavioural T-patterns¹ for the three types of pecking observations, including the total number of pattern occurrences of each type of T-pattern and the percentage composition of each T-pattern type amongst all detected T-patterns. T-patterns were detected in THEME analysis of focal observations 120 s before and after male turkeys exhibited GFP, SFP, or HP² (total length of each observation: 241 s).

Pecking Type	Type of T-Patterns	Pattern Occurrences (n)	Percentage of Detected T-Patterns
SFP	Feed & Forage/Stand/(Feed & Forage)	14	29.17%
	Lying	9	18.75%
	Scratch Flock Mate/Stand/GFP Flock Mate/(Scratch Flock Mate)	7	14.58%
	Drink/Stand	5	10.42%
GFP	Feed & Forage/Stand/(Feed & Forage/(Stand))	80	37.91%
	Other/Feed & Forage/(Other/(Feed & Forage))	18	8.53%
	Stand	17	8.06%
	Lying	14	6.64%
HP	Stand/Walk	18	25.71%
	Feed & Forage/Stand	10	14.29%
	Stand	10	14.29%
	Stand/Walk/HP Flock Mate	6	8.57%

¹ A temporal sequence of two or more behavioural event types occurring more often than expected by chance ($P < 0.005$).

² Gentle feather pecking (GFP), severe feather pecking (SFP), and head pecking (HP)