Movement Disorders
Vol. 15, No. 2, 2000, pp. 328–334

Historical

The Movement Disorder of Nicolas Poussin (1594–1665)

Patrick Haggard, PhD, and Sam Rodgers, BSc

Department of Psychology, University College London, U.K.

Nicholas Poussin (1594–1665) is a key figure in the classic tradition of European visual art. From around 1630 onward his drawings develop a shaky quality, and in a letter dated 1650 he says "le tremblement de mes membres augmente comme les ans."[1] In the absence of detailed evidence, Poussin's movement disorder has been variously ascribed to Parkinson's disease or to neurosyphilis.[2,3]

A retrospective analysis and diagnosis of Poussin's movement disorder presents some interesting challenges to the modern scientist. First, the only available data for studying his behavior is the record left by the pen tip as he moved it across the page over 350 years ago. Second, this data is purely spatial, yet most conventional analyses of movement disorders focus on their temporal characteristics.[4] Third, there is no clear and unambiguous way to distinguish between voluntary modulations of Poussin's pen movement from involuntary tremors. In principle, geometrically identical segments of pen motion could be made as part of the artistic process in one drawing, yet be a consequence of tremor in another drawing. Retrospective tremor analysis thus contrasts with the highly constrained tasks studied in the modern tremor laboratory. Knowing the specific hallmark or kinematic sign of Poussin's movement disorder could assist in authenticating works thought to be by him.

To address these challenges, we have analyzed several features of Poussin's movement in lines taken from selections of Poussin's drawings spanning the period 1625 until 1664. We know from Poussin's own letters that his movement disorder was degenerative, and that it made writing, drawing, and painting progressively harder. Identifying a degenerative trend over this period in a specific parameter of the drawing movement would therefore help to reveal the primary features of Poussin's disorder. These could then be correlated with more detailed kinematic knowledge from modern studies.

BLOT ANALYSIS

We first analyzed the blots at the start of Poussin's lines to investigate whether Poussin had difficulties with initiation of movement. "Freezing," or difficulty in initiating movement, is a common feature of Parkinson's disease, and is often attributed to insufficient excitatory drive from the basal ganglia to the premotor areas of the frontal lobes. We reasoned that a tendency to freeze prior to each drawing stroke would produce a blot at the start of each line as a result of ink absorption by the paper. Further, the blot area would increase with the duration of the freezing. This logic clearly requires the assumption that the pen remains in contact with the paper during the period of freezing.

Method

Six blots were selected from each of 15 drawings.* Because the original folia were typically not available for scanning, we used high-quality reproductions in recognized books and catalogues raisonnees. The local regions of each blot and its immediately subsequent line segment were digitized on a flatbed scanner. Scanning was performed at 508 dpi, at 8-bit resolution, with all automatic settings and optimization suppressed. Blots were defined as line endings which showed a clearly visible widening at the end, which then changed abruptly to a single line stroke. To compensate for the additional influence of nib width on blot area, we also calculated the width of the line segment immediately adjacent to each blot. Each scanned image was thresholded to remove noise, and the blot was separated manually from its accompanying line. The blot area was calculated by counting the number of dark pixels in the blot. The width of the accompanying line segment was estimated by fitting an ellipse to the dark pixels in the line and calculating the minor axis length. This fitting procedure avoids arbitrary decisions

Received September 29, 1998; revision received August 21, 1999. Accepted November 18, 1999.

Address correspondence and reprint requests to Patrick Haggard, PhD, Department of Psychology, University College London, Gower St., London WC1E 6BT, U.K.

about the point along the line at which the width should be measured. Because the line widths are often low relative to the image resolution and are contaminated by non-kinematic artifacts such as paper texture, we wanted to avoid a single point of width measurement. The size of each sheet given in the source catalog was used to scale each measurement to the physical units of Poussin's original pen movement.

Results and Discussion

Typical drawings from the early and later periods are shown in Figures 1 and 2, respectively. The mean blot area was 1.09 mm^2, with a standard deviation of 0.883 mm^2 across all 90 blots and of 0.619 mm^2 across the 15 drawings studied. The mean width of the subsequent line, as measured by the minor ellipse axis, was 0.55 mm (standard deviation 0.228 across blots, 0.158 across drawings). We fitted a multiple regression model to the blot data in which the area of each blot was predicted from the adjacent line width and the year of drawing. The results showed a strong dependence of blot area on line width ($t[87] = 6.216$, $r^2 = 0.303$, $p < 0.001$). However, the date of drawings was not a good predictor of blot size ($t[87] = 0.818$, $r^2 < 0.001$, $p = 0.416$).

A degenerative disorder of movement initiation would predict increasing blot size with age. We found no evidence that Poussin's movement disorder affected the initiation of the drawing stroke in a degenerative manner.

TREMOR ANALYSIS

Our second analysis focused on tremor during Poussin's movement execution. Analyzing tremor in line drawing raises two specific problems. First, conventional time series measures of tremor[4] do not transfer straightforwardly to spatial drawing data. Second, straightforward measurements of line curvature cannot be used to compare tremor across lines and across drawings, because the line curvature caused by tremor is intermixed with other, intentional sources of curvature, such as whether the artist is representing a curved object, and the scale at which that object is represented.

Method

Our tremor analyses therefore studied the modulation of direction within each drawing arc, rather than the Cartesian displacement of the nib itself. Six lines were selected from a group of 15 drawings of which six had been previously used in blot analysis.† We tried to select similar representations in each picture wherever possible to reduce selection bias. Thus, several lines analyzed represented human arms and "straight" architectural edges, although other representations were also analyzed in most cases. The lines were scanned and thresholded as before, then skeletonized and seeded to represent each line as a progression of x,y coordinates. The series of x and y coordinates were differentiated, and the resulting

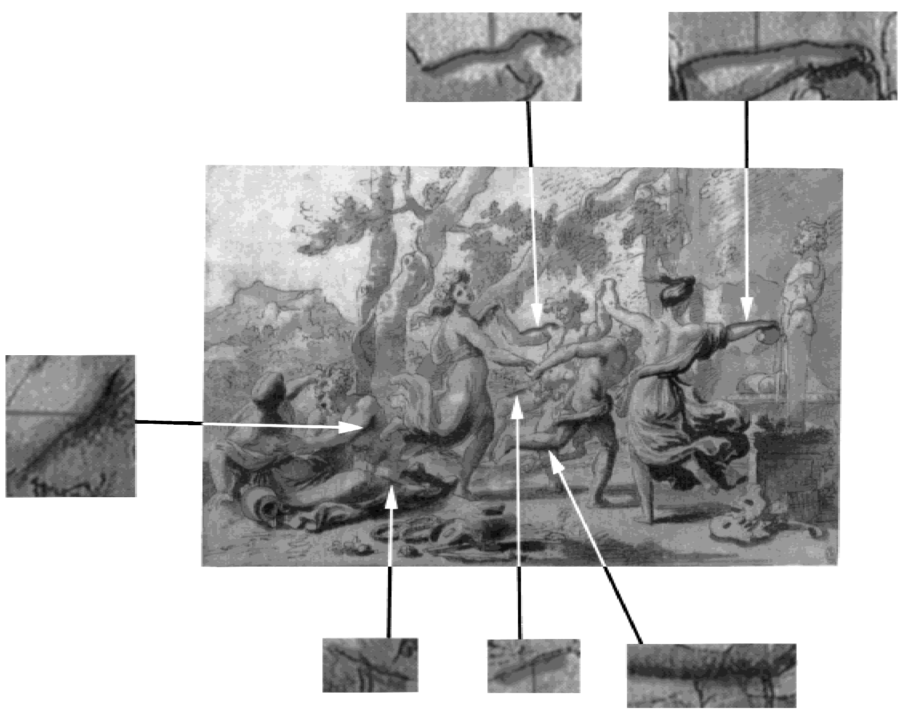

FIG. 1. Bacchanale pres d'un terme (1629). This drawing was selected for both blot analysis and tremor analysis, as representative of the early period of Poussin's work studied here. The six line segments used for tremor analysis are highlighted.

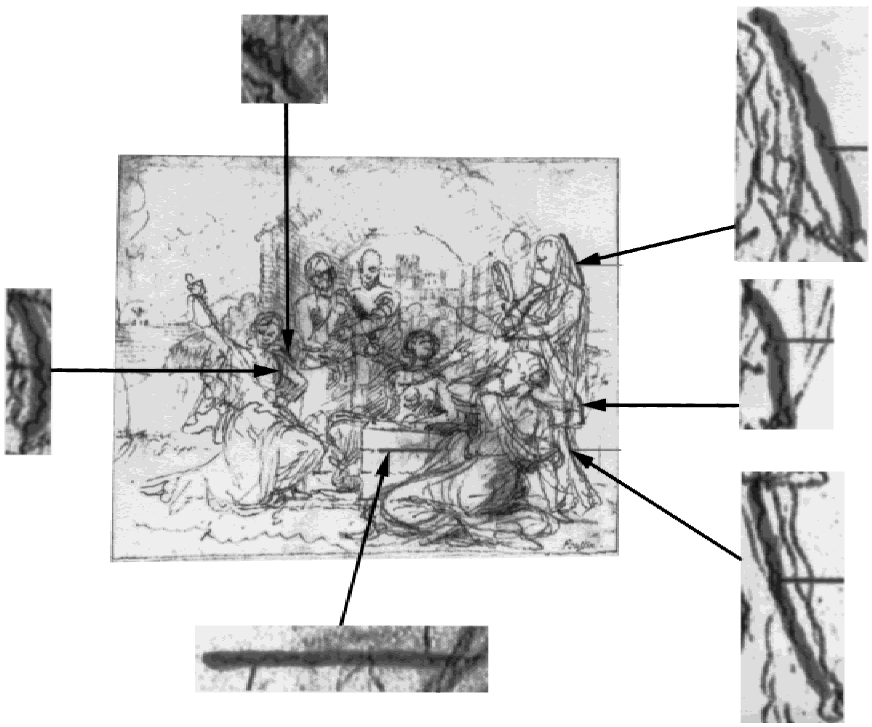

FIG. 2. Achilles parmi les filles de Lycomede (1656). This drawing was selected for both blot analysis and tremor analysis, as representative of Poussin's later period. The six line segments used for tremor analysis are highlighted. Note the high-frequency oscillations in pen movement. Note also the blots at the start of many strokes.

vector was converted to polar coordinates to represent the change in direction as a function of progress along the path. An additional phase-unwrapping stage was applied to prevent discontinuities in direction change across the $0–2\pi$ boundary. The direction change was then numerically integrated (using signed integration), then resampled every 0.25 mm along the path, and low-pass filtered with a 1 mm cut-off. This process unravels arcs of a circle into a straight line, because the direction changes at a constant rate as the arc is followed. We then fitted a linear regression to the directional change and calculated the residuals, thus removing the contribution of the primary drawing arc. The primary arc was removed because it is assumed to be intentional,[5] rather than a consequence of tremor, and because its geometry varies with the shape of the item being drawn. The residual directional change is independent of the primary drawing arc and is assumed to reflect tremor. The following measures were then calculated from the residual tremor for each line: the root mean square (RMS) of the tremor signal, the peak of the amplitude spectrum, and the *spatial distance* along the drawing arc corresponding to a complete cycle of tremor at the amplitude spectral peak value.‡ The means of these measures across the six lines selected from each drawing were predicted from the dates in three separate linear regressions to investigate the degenerative nature of the tremor.§

Finally, we wanted to be sure that our tremor measures reflected genuine changes in the pen path rather than the distorting effects of the dimpled texture of Poussin's paper. We therefore also measured the interdimple distance in each of the 15 pictures used in this analysis from regions of the image where the paper texture could clearly be seen.

Results

The mean interdimple distance in the 15 images was 0.335 mm (standard deviation 0.134 mm).

Typical drawings from the early and later periods are shown in Figures 1 and 2, respectively.

RMS of the tremor signal increased significantly with age: $t[13] = 3.328$, $p = 0.005$, as did the peak of the amplitude spectrum ($t[13] = 3.124$, $p = 0.002$). The spatial distance of this spectral peak decreased with age: $t[13] = -5.335$, $p < 0.001$. The spatial distance of the tremor is typically an order of magnitude larger than the interdimple distance of Poussin's paper. Thus, the tremor is unlikely to be an artifact. These changes in tremor parameters are shown in Figures 3, 4, and 5, respectively. For the earliest drawings analyzed (up to 1630), one complete tremor cycle occurred for approximately every 15 mm of pen movement. By the 1650s, the spatial distance of the tremor peak was much reduced, with one tremor cycle occurring for approximately every 6 mm of pen movement.

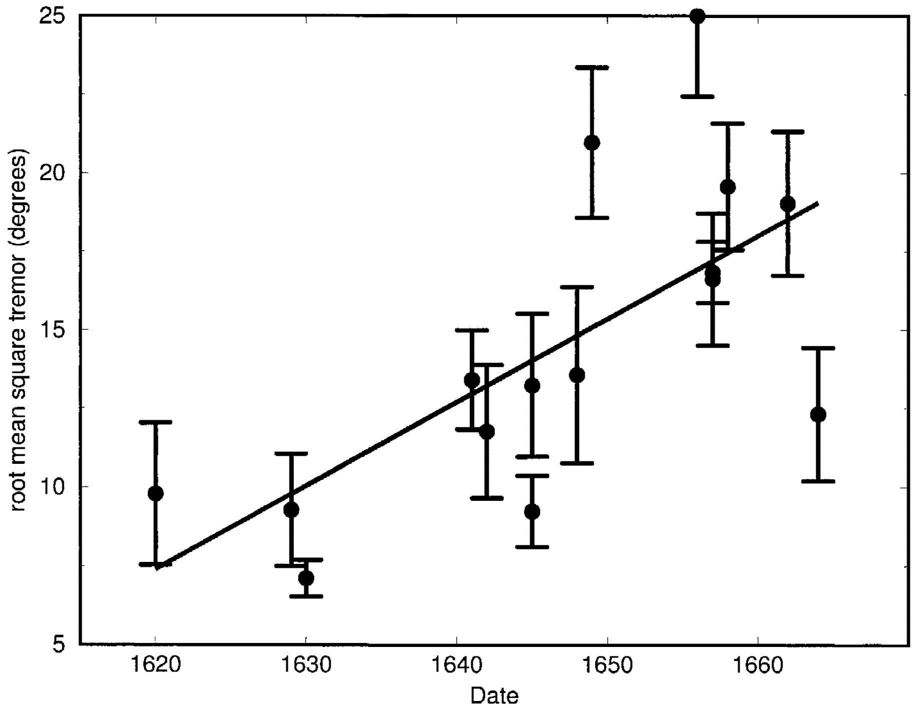

FIG. 3. Changes in root mean square (RMS) residual tremor with age across the 15 drawings selected for tremor analysis. The error bars indicate the standard deviation of RMS tremor across the six line segments selected from each drawing.

We have also analyzed the variable error (standard deviation) of the spatial distance of the spectral peak. This measure corresponds to the height of the error bars shown in Figure 5. Variable error decreased significantly with age ($t[13] = 3.268$, $p = 0.006$). In a drawing from 1629, for example, the standard deviation of the peak tremor distance was 10.6 mm, but in a drawing from 1658 it was only 0.9 mm. In other words, Poussin's drawing became increasingly stereotyped, and his lines became dominated by a consistent tremor oscillation as his disorder progressed.

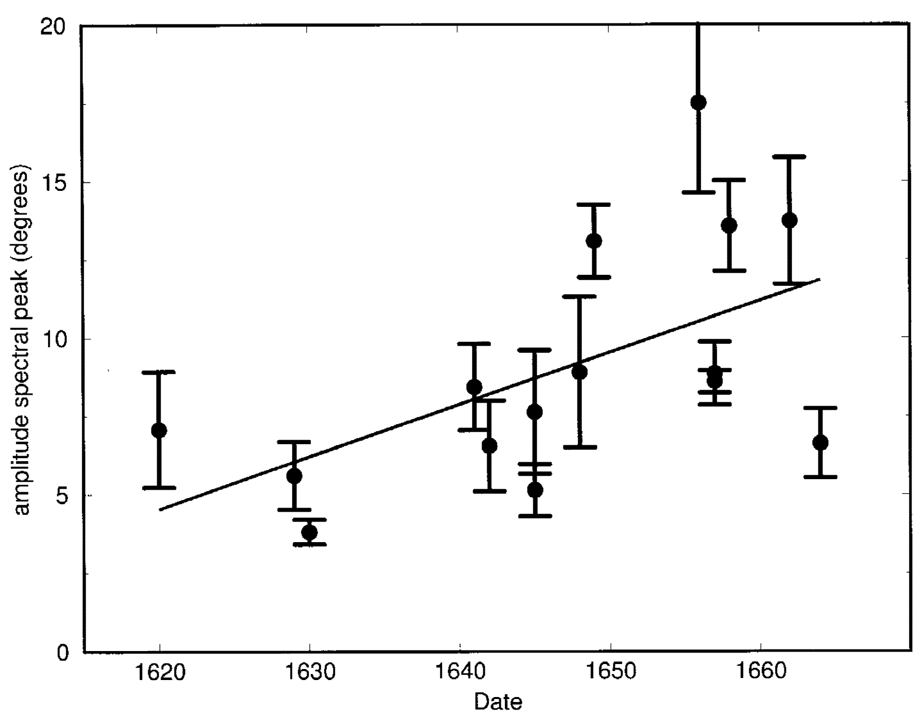

FIG. 4. Changes in peak value of the amplitude spectrum of residual tremor with age. Plotting conventions as for Figure 3.

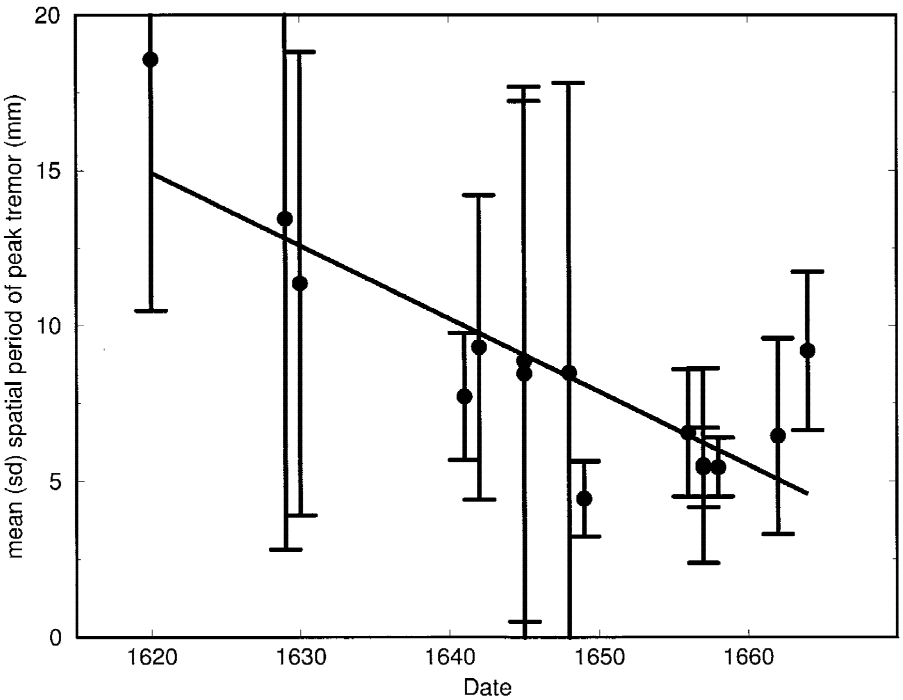

FIG. 5. Changes in spatial distance of the amplitude spectral peak with age. Plotting conventions as for Figure 3.

Discussion

Our results document quantitatively the increasing shakiness of Poussin's hand in his later drawings. Poussin scholars have already commented on the visible shakiness of his later drawings.[2,3] Both our measures of tremor severity suggested a continuous degeneration in Poussin's drawing movement. Nevertheless, we note that some late drawings not in our sample seem to show negligible tremor. The reasons for this interdrawing variability in tremor are unclear. However, many movement disorders do involve variations in tremor severity, for example, with levels of fatigue.

Analyses of the spatial distance of the spectral tremor peak shed additional light on the nature of Poussin's movement disorder. The reduction in the mean spatial distance of the tremor peak with age could reflect one of two possible motor phenomena. First, the speed of Poussin's movement could have decreased, whereas temporal tremor frequency remained constant. Second, his movement speed could have remained constant, whereas the temporal tremor frequency increased. Neurologic tremors are often thought to have a characteristic and stable temporal frequency, arising from the time constants of the underlying neural circuits,[4] although laboratory studies of tremor typically do not have the 40-year time scale of our study. Thus, some increase in Poussin's tremor frequency over time is conceivable. Nevertheless, the near threefold decrease in tremor spatial distance (from the regression line in Figure 5) would require a threefold increase in tremor frequency, and changes of this size have not been reported. Therefore, reduction in movement speed seems a more likely possibility than increase in tremor frequency. Our results thus suggest a progressive slowing of Poussin's drawing movements reminiscent of bradykinesia.

Further, Poussin's ability to make flexible, adaptive drawing motions also degenerated over time. In his earlier work, the spatial tremor distance varied widely between different lines in the same drawing. If we again assume a constant temporal tremor frequency, this finding suggests Poussin initially used a relatively wide repertoire of movement speeds, presumably selecting between brisk, bold strokes and slower, finer actions according to his artistic intention and the demands of the pictorial representation. At the end of his life, Poussin's drawing movements appear more stereotyped: we found an order of magnitude less variation in the tremor characteristics of different lines within the same drawing (measured by variable error of spatial distance of tremor peak). We conclude that Poussin's ability to make truly voluntary movements progressively declined, and his movement kinematics became dominated by involuntary tremor. His movement disorder appeared not to allow him to suppress his tremor for the purpose of specific drawing movements. Bain et al.[6] have suggested that many or most patients with essential tremor and benign familial tremor can achieve voluntary suppression of tremor and frequently do so in everyday motor tasks. Poussin appeared not to enjoy this ability, suggesting that his movement disorder did not follow the typical pattern of these benign tremors.

GENERAL DISCUSSION AND CONCLUSIONS

Taking these results together, we have a picture of a movement disorder which involved a visible shaking of the hand, a marked decrease in movement velocity, and an apparent inability to modulate movement speed voluntarily. Movement initiation, in contrast, was relatively preserved. What possible diagnosis or description of symptoms does this set of signs suggest? First, our analyses confirm that Poussin's action tremor was both prominent and became worse over time. However, many neurologic disorders cause tremor, so tremor is not in itself diagnostic. However, tremors can be divided into three broad behavioral classes: resting tremors, postural tremors, and action tremors, according to the circumstances in which they are most prominent. Our analyses show that Poussin's tremor was an action tremor, because it appeared in the voluntary action of drawing. Of course, we have no graphic evidence whether or not he also had a resting tremor. However, the relatively fine scale of tremor seen in the drawings throughout this period suggest that Poussin did not have the sort of ataxic intention tremor typically associated with cerebellar disorders.[7] Rather, his tremor was regular and he showed no signs of losing control of the primary movement. The primary movement routine appeared intact even toward the end of his life, but had an action tremor superimposed on it. Most cerebellar degenerative disorders, in contrast, lead to increasingly ataxic movements with progressively violent tremor. Poussin is thought to have contracted a venereal disease in 1630,[2] making an ataxic movement disorder resulting from neurosyphilis possible. However, our finding of a progressively reducing spectral tremor distance, however, seems inconsistent with an ataxia.

Poussin's later drawings often use small hooked lines to represent details which he executed with a single, much larger stroke earlier in his career. The significant reduction over time in the tremor spatial distance confirms this impression. Second, the variable error of the spatial distance also decreased, indicating a more stereotyped set of movements. Both findings are consistent with a decline in voluntary force production. Early in his career, Poussin had the full intentional control of his pen movement that representational drawing requires. Late in life, his representations relied on piecing together many repetitions of smaller pen movements. The significant reduction over time of his individual drawing strokes is reminiscent of micrographia (abnormally small writing). Micrographia is an accepted part of the clinical picture of Parkinson's disease.[8] It is generally demonstrated by the decrease in size over time of comparable handwriting examples, such as check signatures, which might be expected to be comparable. Our analyses were of pen strokes intended to represent a range of features and at a range of scales, so the controlled conditions of handwriting signature reproduction do not apply. However, our tremor spatial distance does suggest a reduction of manual movement which may be comparable to micrographia. Analysis of the manuscript copies of Poussin's letters,[1] which were not available to us, would be an interesting topic for future research.

To conclude, our investigations suggest that Poussin had a severe and degenerative movement disorder during the latter years of his life. The major signs of the movement disorder appeared to be tremor and a reduced capacity for voluntary movement, without any documentable evidence of freezing or any loss of the ability to execute the basic forms of movement of the kind associated with ataxia. This is consistent with some forms of the parkinsonian syndrome, so we hypothesize that Poussin had Parkinson's disease. Clearly, a strong claim of diagnosis would require a contemporary study of tremor of the drawing of one or more patients diagnosed with Parkinson's disease. This study would demonstrate degeneration over time in the same measures of drawing that we have analyzed here. In the absence of such a study, we must rely on the general consensus that tremors increase in severity as all degenerative diseases progress. We must also regard our conclusions from the current study as tentative.

Interestingly, the tremor so clearly visible in his drawings is less apparent in his paintings of similar dates. Instead, his later paintings often show a drop in outline definition.[‖] We can imagine several possible reasons for this difference between drawings and paintings. First, Poussin's tremor may have been partly task-specific: other basal ganglia disorders such as writer's cramp are now thought to be so.[9] The movements used in painting may have been sufficiently different from those required for drawing for the disorder to be less apparent. Second, the flexibility of the paintbrush might damp out the manual tremor, producing an indistinct but non-oscillating line. A final possibility, that parts of the pictures may have been painted by other hands, seems unlikely given the documented evidence that Poussin did not use assistants in his later work. Our research opens the intriguing possibility of using spatial tremor analysis to date and/or authenticate drawings attributed to Poussin in the future.

Finally, the conclusions of this study should be subject to a number of qualifications. First, our dataset inevitably involved selecting a small number of drawings from Poussin's oeuvre and selecting a small number of line segments from each drawing. Our selection criteria were based on the dates of the drawings, the image quality, the presence of analyzable blots and lines, and congruence of represented material such as human arms and architectural details. Because the selection of data was not blind, we cannot exclude the possibility of a selection bias. Second, we have assumed that Poussin's drawing movements consisted of a low-frequency voluntary or representational arc on which a high-frequency involuntary tremor component is superimposed. We have also assumed that blots arise from unintended delays in initiating drawing movements. We think some assumptions along these lines are necessary given the nature of the movement data in this case. Finally, there is no surviving independent evidence regarding Poussin's intentions, so we cannot be certain whether a particular line segment is voluntary or involuntary. Indeed, measurements from the earlier drawings in our sample may be dominated by voluntary modulation of the pen path, whereas measurements from later drawings may be dominated by tremor. As such, the age-related changes in Poussin's tremor may in fact be underestimated by our procedures.

Acknowledgments: The authors thank Martin Clayton and John Stein for their valuable comments on an earlier draft.

REFERENCES

1. Jouanny CH. *Correspondance de Nicolas Poussin.* Paris: Societe de L'Histoire de l'Art Francais, 1968.
2. Blunt A. *The Drawings of Poussin.* New Haven, CT: Yale University Press, 1979.
3. Verdi R. *Nicolas Poussin.* London: Zwemmer, 1995.
4. Elble RJ, Koller WC. *Tremor.* Baltimore, MD: Johns Hopkins, 1990.
5. Van Sommers P. *Drawing and Cognition.* Cambridge: Cambridge University Press, 1984.
6. Bain PG, Mally J, Gresty M, Findley LJ. Assessing the impact of essential tremor on upper limb function. *J Neurol* 1993;241:54–61.
7. Hore J, Wild B, Diener HC. Cerebellar dysmetria at the elbow, wrist and fingers. *J Neurophysiol* 1991;65:563–571.
8. McClellan JE, Nakano K, Tyler HR, Schwab RS. Micrographia in Parkinson's disease. *J Neurol Sci* 1972;15:141–152.
9. Marsden CD, Sheehy MP. Writer's cramp. *Trends Neurosci* 1990; 13:148–153.
10. Rosenberg P, Prat L-A. Nicolas Poussin 1594–1665. *Catalogue raisonee de dessins.* Milan: Leonardo, 1994.
11. Day BL, Thompson PD, Harding AE, Marsden CD. Influence of vision on upper limb reaching movements in patients with cerebellar ataxia. *Brain* 1998;121:357–372.

NOTES

*The drawings selected for blot analysis were as follows. The titles are as given in Rosenberg and Prat,[10] and the second number in parentheses indicates the Rosenberg and Prat plate number.

La bataille de Josue contre les Amelikites (1626) (25)
Acis et Galatea (1627) (29)
Bacchanale pres d'un terme (1629) (57)
Le Marriage (1636) (102)
L'enlevement des Sabines (1637) (147)
La Confirmation (1640) (107)
Moise enfant foulant aux pieds de la couronne de Pharaon (1645) (297)
Achilles parmi les filles de Lycomede (1656) (362)
Le repos pendant la fuite en Egypte (1657) (361)
Apollon Sauroctone (1657) (374)
Trois nymphes epiees par deux satyres (1662) (379)
Apollon Berger (1663) (380)
Apollon amoureux de Daphne (1664) (382)

†The drawings selected for tremor analysis were as follows. The titles are as given in Rosenberg and Prat,[10] and the second number in parentheses indicates the Rosenberg and Prat plate number.

Abraham chassant Agar et Ismael (1625) (20)
Bacchanale pres d'un terme (1629) (57)
Apollon et les muses sur le mont Parnasse (1630) (37)
Sainte Famille avec Saint Elisabeth et Saint Jean-Baptiste enfant (1641) (223)
Scipion et les pirates (1642) (221)
Moise enfant foulant aux pieds de la couronne de Pharaon (1645) (297)
La Confirmation (1645) (108)
Sainte Famille a l'escalier avec un vase contenant fleurs (1648) (314)
La Conversion de Saint Paul (1649) (340)
Achilles parmi les filles de Lycomede (1656) (362)
Apollon Sauroctone (1657) (374)
Couple de bergers dans un paysage (1657) (372)
La conversion de Saint Paul (1658) (370)
Trois nymphes epiees par deux satyres (1662) (379)
Apollon amoureux de Daphne (1664) (380)

‡Our spatial distance measure is the spatial equivalent of the period of peak tremor frequency. However, we have avoided the term "period" to prevent confusion with the more common temporal use of the term.

§Our direction change analysis is related to that proposed by Day et al.[11] for measuring deviations in reaching trajectories of cerebellar patients. Their analysis, unlike ours, involves cumulating the unsigned integral of directional change throughout the movement.

‖We are particularly grateful to Martin Clayton for his helpful comments on this point.